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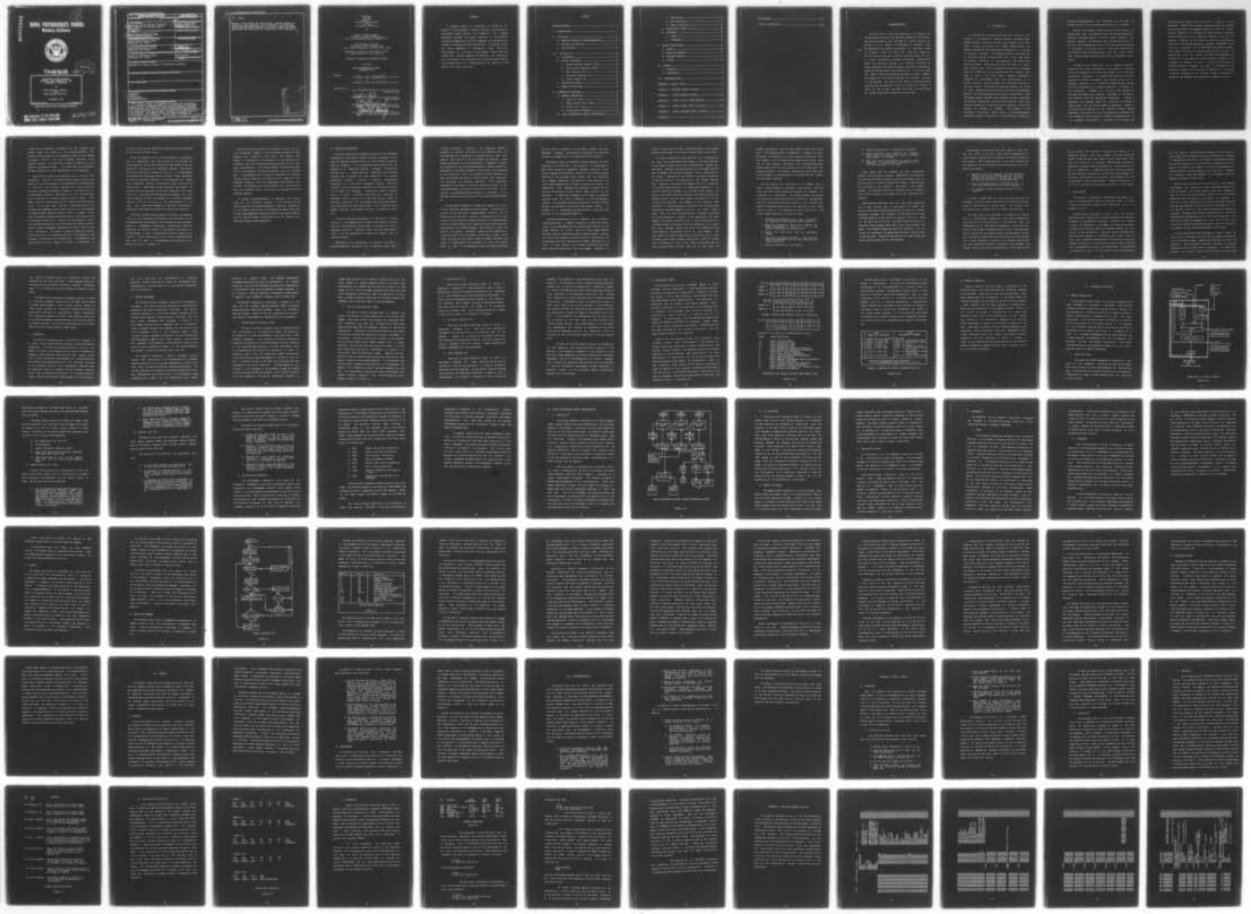

NAVAL POSTGRADUATE SCHOOL
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THESIS

EMULATION OF THE AN/UYK-7
TACTICAL DATA COMPUTER ON THE
BURROUGH'S D-MACHINE

by

Jerry Michael Haggerty
and
John Michael Hartling

December 1976

Thesis Advisor: S. Jauregui

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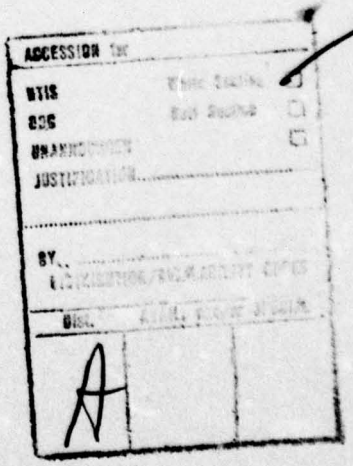

Emulation of the AN/UYK-7 Tactical Data Computer on the Burrough's D-Machine

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ABSTRACT

A workable design is presented for emulating the AN/UYK-7 multiprocessing computer system on the Burrough's Interpreter Based System, the D-Machine. The program developed provides for exact execution of the AN/UYK-7 instruction repertoire with the exception of Floating Point, hardware interrupts and IOC Instructions. The design allows for future expansion to incorporate these functions. Input/Output is limited to a card reader, line printer and single disk. Various aspects of Emulation, the D-Machine, and the AN/UYK-7 are discussed and a detailed User's Manual is provided along with recommendations for modifying the design into a full emulation.

CONTENTS

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I. INTRODUCTION

In its effort to provide the Fleet with officers well versed in all aspects of Computer Science, the Naval Postgraduate School strives to furnish each student in the Computer Science Curriculum with ample opportunities for hands-on operation and programming experience on a variety of computer systems. The systems presently available for this purpose include the IBM 360/67, PDP 11/45, XDS 9300, and several varieties of microcomputers and stand alone graphic systems. Unfortunately, this wide range of available systems and their incorporated programming languages does not include any of the numerous tactical computer systems in use in the Fleet today; moreover, because of budgetary and procurement lead time constraints, it is highly unlikely that the school will have such a system in the near future. To provide the desired systems, the Chief of Naval Education and Training and the Naval Postgraduate School, with the assistance of Burrough's Corporation, have provided a medium through which students may gain experience and perform research on, not one or two Tactical Data Systems but potentially on any particular computer in which the student may express an interest. This medium is the Burrough's Interpreter Based System, a microprogrammable computer, hereafter referred to as the Burrough's D-Machine.

Through microprogramming, the D-Machine can be made to operate exactly like any designated computer of interest.

Through the process of Emulation the authors sought to demonstrate that the D-Machine could be microprogrammed to imitate a selected computer. As the target computer, the authors selected the AN/UYK-7 which is used extensively in Tactical Data Systems and is one of the more complex systems in use today. It was felt that if a realistic emulation of the AN/UYK-7 could be demonstrated, then any lower level, less sophisticated computer could also be successfully emulated.

The goal of this thesis was not a complete AN/UYK-7 emulation, but rather development of the design for the Emulation, and adoption of a sufficient subset of the AN/UYK-7 instruction repertoire to demonstrate exact and efficient execution of AN/UYK-7 programs. The design allows for a complete emulation of all AN/UYK-7 functions and provides for future expansion to a complete emulation including all IOC Functions. Chapters II, III and IV are designed to provide the reader with a general knowledge of Emulation, the AN/UYK-7 and the Burrough's D-Machine. Chapter V describes the methods used for imitating the AN/UYK-7 instructions and its various modes of operation. Chapter V also defines the mapping of the AN/UYK-7 Control Memory Registers and status bits into the Burrough's D-Machine for the purpose of this Emulation. Chapter VI presents some of the problems encountered in the course of this thesis, and

the conclusions drawn by the authors as a result of this Emulation. Chapter VII provides recommendations for expanding this Emulation and suggests possible follow on thesis topics. Appendix A is included as a User's Manual, and contains information on how to use the D-Machine, how to run AN/UYK-7 programs on the Emulator, and how to use special features of the microprogramming language TRANSLANG which were not documented in the TRANSLANG Programmer's Manual. The program listings of the Loader and Emulator, written in association with this thesis and used to demonstrate the feasibility of the design by running AN/UYK-7 Programs, are included as Appendix B and C. A sort routine written in AN/UYK-7 machine language, and used to demonstrate the Emulator's capability is provided in Appendix D. The output of the sort program and the optional Loader functions of assembler and debugger are presented as Appendix E and F.

II. EMULATION

Modern computer systems are generally composed of five basic units: input, output, memory, arithmetic/logic, and control. The instruction execution and communications among these units are usually well understood with the exception of the control unit which is, typically, understood only by the system engineer. The control unit generates the signals necessary for the information flow and timing of the system. In conventional computers this is done through the use of flip-flops (e.g. registers and counters) and gates designed in a relatively ad hoc manner. Microprogramming the control unit has been proposed as an orderly alternative to this ad hoc design procedure where the hardware of the control section is replaced by a "microprogram control" unit.

Microprogramming is therefore a technique for implementing the control function of a digital computer using programmable control signals stored in a separate, word-organized memory, called control store. If the control store were a programmable memory, then the system architecture could be modified to optimize processing of each task to be performed; moreover, it could be altered completely to resemble the architecture of another, entirely different machine. The microprogramming of the control store of a computer system to alter the basic architecture enabling one

machine (the host machine) to execute machine language programs intended for another machine (the target machine) is defined as Emulation.

The remainder of this chapter is divided into three sections: general information on microprogramming, construction of an emulator and applications of emulation.

A. GENERAL CONCEPTS OF MICROPROGRAMMING

Since the cost of software has become a major portion of the overall cost of computer systems today, more and more manufacturers and users are turning to microprogramming the control section of their computer to tailor the machine to individual applications, thereby making computer programming more efficient.

The main function of the control section is to specify the conditions under which sets of gates are to be opened. In conventional machines this can lead to a very complex, hardwired system, especially if the instruction set is extensive. A relatively simple field change, addition or alteration, may require a major modification of this complex system. This is not true in a computer that uses a microprogrammable control store. The complex hardwired structure is replaced by microinstructions stored in the control store, one microinstruction per word, which tell the system which arithmetic and logic operations to perform by specifying which gates to enable/disable. In this way,

control of the computer is removed from the hardware and placed under the control of the microprogrammer. This places a heavy burden on the programmer since he must become intimately familiar with the innermost workings of the machine; however, it allows him to model the machine to his specific programming needs. This gives the microprogrammer extreme flexibility in his applications on the computer.

There are two types of microinstructions: vertical and horizontal. Vertical microinstructions usually control one operation; and the address of the successor microinstruction is implicitly the current address plus one, unless the current microoperation causes a branch. In horizontally microprogrammed machines each control bit of a microinstruction is assigned to a specific gate or set of gates. This means that one microinstruction can control multiple operations. On the other hand, vertical microinstructions are divided into separate fields, each of which are then decoded to enable/disable specific gates or sets of gates; therefore, horizontal microinstructions require less decoding and provide more flexibility. However, the advantage of vertical microinstructions is that they generally require shorter control words considerably reducing the overall cost of control micromemory. The length of control words vary from 20 bits (vertical) to in excess of 120 bits (horizontal); the average microinstruction is 50-80 bits. The D-Machine, the host machine for this thesis, utilizes a combination of

vertical (Type II) and horizontal (Type I) microinstructions in the form of a 56-bit word.

Since the execution time of one horizontal microinstruction is essentially the same as that of one vertical microinstruction, the multiple operations performed during one horizontal instruction is a desirable feature. This parallelism can drastically reduce the size of a microprogram, and dramatically decrease execution times. These reductions can only be realized, however, if the programmer can recognize concurrent actions and optimally group them into one instruction. A great deal of work has been done toward including the efficient use of available resources into a compiler for a high-level microprogramming language, but with little success. Either the probability of making the determination is low, or the cost of the optimization is too high. Much additional research is required in the area of recognizing and combining potentially concurrent actions.

Different microintructions specify different microoperations to be performed, and depending on the nature of the microoperations, some phase of one instruction may overlap a phase of a subsequent instruction. Instruction timing is, therefore, an important factor in the overall efficiency of microprograms in which microoperations are not mutually exclusive. A brief description of the timing considerations that must be made in microprogramming the Burrough's D-Machine is given in Chapter IV.

Many main-frame manufacturers hesitate to allow the novice programmer access to the innermost workings of their computer (e.g. registers, data paths, and gates). One method of prohibiting this access is to use read-only micromemory with the microprograms being provided by the computer manufacturer. This helps preserve the designed identity of the computer but does not provide for its optimum use. The programmer who is given the capability of modifying the logical design of the machine to his specific programming needs will find his programming tasks greatly simplified. For example, he could implement new instructions, such as floating point, which were not designed into the original machine.

In summary, microprogramming is becoming more widely used for the following reasons: 1) the flexibility and growth potential of microprogrammable machines (especially in the area of emulation), 2) increasing software costs and current semi-conductor technology favor microprogram design, and 3) user-oriented instructions can be designed into machines through microprogramming.

B. BUILDING AN EMULATOR

Emulation describes a process through which the hardware components of one machine (host) are made to "appear" to assume the specific characteristics of the hardware of another machine (target). This provides the host machine with the capability of executing machine language instructions written for the target machine. Simulation is a software process that provides the same capability for program execution; however, simulation involves interpretive execution by a high-level language program. Emulation differs in that an emulator performs its interpretive execution through the hardware. Simulations usually perform within a factor of 100-200 times real-time. Emulation is generally within a factor of 10, but often can be tuned to approach real-time. For this reason emulations are usually more cost-effective than simulations. The following paragraphs describe the process involved in building an emulator.

There are two major approaches to emulating a target machine: 1) the hardware and firmware (the physical realization of a microprogram) can be used in conjunction with a software simulator (software alone would be pure simulation), or 2) the hardware and firmware can execute with no software support.

Depending on the percentage of software utilized, a software-assisted emulation may be somewhat slower than a

firmware emulation. Typically, the programmer mentally develops a software simulation of the target machine. He then decides which sequences of instructions are most frequently used, and which are the hardest to simulate. These become candidates for microprogramming. Frequently a single new instruction can be microprogrammed to replace repetitive sequences of the same high-level instructions, thus speeding up the emulation. With this software-firmware approach the user must decide the point at which he must stop substituting microcode for software routines. This is generally dependent on the amount of control storage available, or the cost-performance criteria with which he is working. An example of a software-hardware approach to emulation is the IBM 7000 series emulators used with the IBM System/360 Model 65.

The Burrough's D-Machine provides the capability of emulation using the software-hardware method. A simulation is written in the high-level language ALGOL. ALGOL on the D-Machine allows the user to define a new operator which, when called in the simulation program, branchs to a preprogrammed series of microinstructions; executes the microinstructions; and returns to the ALGOL program. This gives the user the ability to execute frequently used routines (such as instruction fetch) from micromemory which has a faster cycle time than that of main memory where the ALGOL simulator resides. An advantage to this approach is that the system does not have to be regenerated after different emulators

are run since, in essence, only an ALGOL program has been executed. However, as previously discussed, this software emulator is slower than a firmware-controlled emulator.

The authors used the hardware-firmware approach in their emulation of the AN/UYK-7. This method will be developed in more detail along with suggested hardware additions which could enhance the emulation. Control of the system resides entirely in the firmware, which means that the emulator, once loaded, dedicates the machine to that emulation, and native mode programs can no longer execute until system regeneration. This unproductive overhead of loading and reloading the emulator and the native mode machine is one drawback. An additional drawback is the larger micromemory required since the entire emulation is microprogrammed. However, the emulator executes exclusively through firmware making this approach to emulation significantly faster. An example of a firmware-controlled emulator is the IBM 1401 emulator on the System/360 Model 30.

Although systems such as the D-Machine use horizontal microinstructions to enable parallel or concurrent operations, the microprogram can only perform one function of the target machine at a time. That is, if the target machine performs parallel operations such as executing one instruction while simultaneously fetching the next instruction, the microprogram can only emulate one of these functions at a time. It must execute the current instruction and then fetch the next instruction. For this reason, emulation is

usually slower than the real time performance of the target machine even though it may have a faster memory cycle time.

In order to emulate a target machine, the microprogrammer must first understand three areas: 1) the host machine, 2) the target machine and 3) the microlanguage. Second, the registers, counters, and accumulators of the target machine must be mapped into the host machine. This is often done in two steps - depending on the number of available registers in the host machine. The registers of the target machine most frequently used should be mapped directly to registers in the host where possible. The remaining registers of the emulated machine are mapped into the host's main memory. As many of the target machine's registers as possible should be mapped directly, so that fewer memory references will be required by the emulator. For example, if the emulator were executing a Load Accumulator instruction and the specified accumulator had been mapped into one of the host's registers, then only one microinstruction is needed to emulate the load instruction. However, if the accumulator had been mapped to a memory location, then it would take several microinstructions to emulate the entire operation - i.e. setup the store address, store the value to be loaded into the write register, and perform a write to main memory. Not only does this require additional instructions, but it also includes a main memory access, whose cycle time is slower than micromemory's cycle time. Some instructions may require two main memory cycles, such as an ADD where the

mapped accumulator must be read, added to and then written out. This demonstrates the necessity of mapping as many registers as possible to the host machine's hardware. Seldom, however, can this mapping be accomplished without some use of main memory; therefore, the microprogrammer must select some portion of main memory as a privileged area for register mapping. The authors reserved the first 1024 words of main memory in the emulation of the AN/UYK-7, for register and buffer mapping.

The next step in the emulation is to assume that a user's object program is resident in main memory. The emulator must then fetch, decode and execute the program, instruction by instruction. The microprogrammer must decide which emulation functions should be written as subroutines, and which functions should be written in line. The most frequently referenced subroutine in any emulation is the fetch routine since it is executed for every instruction. The normal steps involved in this routine are:

1. Determine the address of the next instruction as indicated by the program address register.
2. Read the instruction from the main memory address calculated in step 1. This is the current instruction to be emulated.
3. Decode the instruction into its designator fields.
4. Calculate the operand address. (The AN/UYK-7 uses a displacement plus an index register plus a base register).
5. Read the operand from main memory.

6. Perform indirection if allowed and indicated.

7. Some instruction sets, AN/UYK-7 for example, allow whole or half-words. Check if current instruction is half-word.

8. Some instruction sets operate on partial word operands. If so determine if quarter, half or full-word operand is to be used.

These steps must be executed for each instruction fetched from the user's program. Depending on the particular instruction being emulated, some of these steps may be omitted (step 8 is only performed for Format I instructions) but the majority are generally applicable. This demonstrates the overhead involved in emulation prior to branching to the microroutine that does the actual instruction execution.

Some hardware additions that can facilitate emulation are a fast shifter and a field select unit (FSU). The shifter simplifies variable-length byte extraction, a common emulation process. For instance, in the D-Machine it takes the same amount of time to shift a word by 1 bit as it does for any shift up to 31 bits. The FSU allows the testing of selected fields without requiring a cycle to go through the adder (the D-Machine does not have this feature). This relieves the programmer of masking and shifting fields prior to testing them. These two features are the most common and cost-effective additions to the hardware.

One approach to emulation that has recently come into use, but which is not that widely used or understood, involves using a combination of hardware, software and operating system. IBM is experimenting in this area, and has established the following design characteristics for the System/370 emulators:

1. Emulators must be integrated with the operating system and run as a problem program. This eliminates the overhead of loading and reloading the emulator and the native mode machines.
2. Allow multiprogramming of emulators as well as a mix of emulators and native mode programs.
3. All programs including emulators must be interruptible.

With such a system IBM felt they could give the user an improved, more efficient environment from which to operate, either in the emulator or native mode. The authors feel this should be a primary field for future applications.

The final item to be discussed in the Section is emulation of Input/Output operations. Most sources agree that emulation of I/O is as difficult, if not more so, than the implementation of the central processor's instruction set. This is true primarily because once the basic routines needed for instruction and operand fetch are programmed, the actual instruction executions are fairly easy to microprogram. This is not necessarily true with I/O - buffers must be set up; data conversion possibly performed; and perhaps the hardest point, emulating circumstances in which results are

not yet known. For instance, if the I/O is to search for a specified record, then what happens if the key cannot be found? There are many such checks or error conditions that make I/O difficult to emulate. Another major problem is emulating interrupt handling during I/O. Since emulation of I/O is essentially a separate topic and since the authors did not implement emulation of the AN/UYK-7 Input/Output instruction set as part of the thesis, I/O emulation will not be described in any further detail. However, references 5, 12, 15, 21, and 22 provide excellent material on this topic.

C. APPLICATIONS

This section is designed to familiarize the reader with some of the applicable areas for emulation usage. It is by no means an exhaustive study of this topic, nor is it intended to be so.

Emulation was first used in, and is still the primary application for, converting from second generation computing systems to third generation systems. Normally, the process is costly and dangerous in the aspect of converting programs running on the existing system to programs capable of executing on the new machine. There are several methods other than emulation capable of performing this task, none of which are completely satisfactory: simulation is slow; automated translation is unproven; and instruction by instruction reprogramming is costly and cumbersome. The advantage of emulation is that if the old machine could be emulated on

the new machine allowing direct execution of all old programs, then the old programs could be converted at leisure, if desired and justified. For example, reprogramming might not be cost effective or justified for a program with an expected life span of six months. In such circumstances continued emulation of the program is the solution. However, the situation might be different if the program had an expected life span of three years.

Another major application for emulation is the design, development, and testing of a newly conceived system on an existing system. The target machine does not necessarily have to be an existing computer system, and the user could experiment with the design of any machine he desires. In this way a richer instruction set can be achieved; moreover, software and diagnostic routines could be developed for the new machine prior to the machine even being produced or marketed. IBM used this method to some extent by emulating System/370 on System/360 prior to building System/370. This application tends to decrease the time from initial construction to marketing because software, such as the operating system, can be tested and debugged concurrently.

A third application, and one seen as a major trend for the future, is the ability of the user to adapt the computer to his individual needs. Modern-day computers are built as powerful, general-purpose machines designed to operate effectively over a large field of problems. In doing so, however, the machine cannot optimize execution of any one

particular application. Emulation gives the user this ability. The user can either operate from an existing emulator, or he can tune the emulator to his individual application through microprogramming. One user may want a machine oriented toward string operations, while another user may be doing extensive scientific calculations. If each user could execute from a separate emulator tuned to his individual application, then each would be more efficient and productive. In addition the computer would probably be easier for the user to program. This is the area where multiprogramming of emulators is projected to be of the most use.

There are several other areas of emulation usage which were not discussed; such as the academic environment for research purposes (the reason for this thesis), and tuning of existing software. However, as previously stated, this section was designed only to give the reader a flavor of the possible uses of emulation and perhaps stimulate his own ideas for possible applications. For additional and more detailed material see references 2, 15 through 18, and 20 through 24.

III. THE AN/UYK-7

This chapter is intended to introduce the reader to those operational characteristics and capabilites of the AN/UYK-7 computer most pertinent to the Emulation. This will assist the reader in understanding the design and mappings used in this Emulation and presented in subsequent chapters. This chapter is not intended to be a technical manual and should not be used for that purpose. The reader should consult references 26 and 27 for more detailed information.

The AN/UYK-7 is a highly reliable, ruggedized, multiprocessor system designed and manufactured by the Univac Division of Sperry Rand Corporation. Built to military specifications (MIL-E-16400), it is utilized extensively throughout the United States Navy in Tactical Data Processing applications [26]. Rapid data transfer rates are provided during communications between external devices, internal random-access memory, and the central processor. The system is capable of average command execution times of 1.5 microseconds, and an input data transfer rate of over one million 32-bit words per second. The AN/UYK-7 maintains two completely separate sets of index, arithmetic and relative address (Base) registers, for use during Task and Executive states. In addition, a set of 18 privileged instructions

with special characteristics for executive control are reserved for the Interrupt State. These features along with the parallelism of AN/UYK-7 field and register references, make it an extremely difficult system to emulate in real-time.

The AN/UYK-7 was designed to operate as either a single or multiple processor system with up to 256K, 32-bit words of random access memory. This allows on-line access to 1024K bytes through an instruction feature which permits whole-word, half-word, or quarter-word memory references. This Emulation assumed an AN/UYK-7 configuration consisting of a single processor, monoprogramming, with one 64K, 32-bit word memory module. Partial word references were fully emulated providing random access to 256K bytes.

A. INTERRUPTS

The AN/UYK-7 processes data in real-time in response to a highly prioritized interrupt system with decision-making properties. This priority system allows the central processor to select that program routine which is necessary to respond to the interrupt requiring the most urgent attention. Since the Emulator was designed for a monoprogramming environment using asynchronous I/O, the interrupt features of the AN/UYK-7 were not fully implemented. Several types of interrupts, such as Program Faults (Illegal Instructions), were implemented and tested. All interrupt handling flags, lockouts and registers were mapped into the Emulator.

This will facilitate full implementation of interrupt features - should a decision be made to incorporate multiprogramming or synchronous I/O in the course of expansion to a full Emulation.

B. CENTRAL PROCESSOR

The AN/UYK-7 central processor contains all the control, arithmetic and timing circuitry required for processing alphanumeric data and for executive functions. The central processor operates in two different modes or states: the Interrupt State executes executive-type functions, and the Task State processes user programs. A group of 16 privileged instructions and a separate set of arithmetic, index and base registers are reserved for the exclusive use of the processor while in the Interrupt State. These features greatly enhance the AN/UYK-7's multiprocessing and multiprogramming capabilities. These special instructions and registers were mapped into the Emulator; however, they were not fully implemented because of the monoprogramming environment in which the Emulator was to be run.

The AN/UYK-7 maintains a central processor control memory (CMR) consisting of 82 integrated-circuit, random-access registers of varying sizes appropriate to their function (e.g. A-registers 32-bits, B-registers 20-bits). The various registers are grouped into stacks according to their use, addressing, and relative size. In the Emulator, these registers were mapped into the D-Machine's main memory

starting at address 0000, with address assignments corresponding exactly to that of the AN/UYK-7. The notable exception was that CMR addresses designated as "Unassigned" in the AN/UYK-7 were used as temporary storage registers in the Emulator. Register mapping is discussed in more detail in Chapter V and presented in tabular form in Figure V-2.

The AN/UYK-7 registers of particular interest to the user are: the Program Address Register (PAR); the Active Status Register (ASR); and the Base, Index and Arithmetic Register groups. These are the only registers which are either directly addressable or accessible to the programmer.

1. Program Address Register (PAR)

The PAR is a 20-bit register used for addressing the next instruction to be fetched from memory for execution. It consists of a 16-bit displacement value and a 3-bit Base Register reference. The effective instruction address is formed by the addition of the displacement and the contents of the selected Base register. The PAR displacement value is incremented by one word at the completion of each instruction cycle with the exception of JUMP instructions. These instructions cause replacement of the PAR by the "s" and "y" operand fields of the JUMP, thus providing for out-of-sequence instruction execution. The PAR mapping in the Emulator is not composed of two separate fields, but rather as the calculated effective address. This greatly simplifies and expedites instruction references; however, it

causes some difficulty with specific instructions which require access to the two separate fields of the PAR. When encountered, this problem was overcome by dividing the PAR value by 8K. Since the Base registers were preinitialized in 8K increments, starting at 1024, the results of the division yielded a quotient equivalent to the Base register assignment, and a remainder equal to the displacement.

2. Active Status Register (ASR)

The ASR is a 23-bit register used to indicate and control the status of various operations in the central processor. Individual bits of the register are assigned special functions, and when set indicate that a particular status exists and that the processor should be controlled accordingly. Individual bits are set/cleared as the result of either an instruction execution or direct processor intervention. The bits of particular interest to the programmer are the arithmetic bits (equal, greater than or equal, overflow, and limits) which are set as the result of arithmetic functions, and may be interrogated by specific instructions, such as conditional jumps. Based on the condition of the bit tested these conditional instructions may cause a change in the program sequence. In the Emulator the ASR bits most frequently referenced by the programmer are mapped into a D-Machine internal register together with the PAR. This considerably reduces main memory references, and reduces Emulator execution time. The ASR mapping is discussed in detail in Chapter V.

3. Base Register (S)

There are two sets (Interrupt, Task) of 18-bit S-Registers, numbered 0-7. These registers, used in final Y-Operand and instruction address calculations, are necessary in a multiprogramming and multiprocessing environment. In spite of the monoprogrammming environment of the Emulator, the registers were mapped and used as designed; however, they were preinitialized by the Loader at 8K boundaries starting at address 1024. This provided the Emulator access to 64K of main memory in increments of 8K pages.

4. Arithmetic Register (A)

There are two sets (Interrrupt, Task) of 32-bit A-Registers, numbered 0-7. They are used extensively throughout the instruction set to hold one or more of the operand - inputs to, or results of arithmetic functions. The A-Registers also serve as the main interface between the central processor and main memory. These registers are directly addressable by the programmer.

5. Index Register (B)

There are two sets (Interrupt, Task) of 20-bit B-Registers, numbered 1-7. These registers can be used as counters, or they can be employed in a special addressing technique called Indexing. During normal Y-Operand address calculations, the designated B-Register is added to the y-displacement and a specific S-Register to form an effective

address. This address is then considered to have been indexed by the B-Register value. Indexing provides the programmer with the option of sequentially referencing memory by merely incrementing the index during each pass through a loop. Reference to any B-Register other than B(0) implies that indexing is to take place during the Y-Operand address calculation. A reference to B(0) is treated as an index of zero since B(0) is not a valid register. In the Emulator, the contents of B(0) is always zero, and references to B(0) are conveniently treated the same as references to B(1) thru B(7). In the AN/UYK-7, the B-Registers have the same internal structure as the PAR; that is, they consist of two fields (a Base register, and a displacement). In the Emulator, B-Registers are treated as consisting of one field which can be separated into its two respective fields by division by 8K, as previously described in the PAR discussion.

In order to minimize access time and field decoding, all CMR registers were treated as 32-bit registers in the Emulator. This caused no problems with the exception of the PAR and Index Registers, which were resolved as previously discussed. The A, S, and B-Registers are directly addressable through the Load/Store CMR Instructions of the AN/UYK-7. They are incidentally addressable through references in specific fields of the different Format instructions reserved for that purpose.

C. INSTRUCTION FORMAT

Instructions of the central processor appear in five different formats according to their operational characteristics, as presented in Figure III-1. Formats I, II, and III occupy a full, 32-bit computer word; Formats IV-A and IV-B each occupy a half computer word. Two half-word instructions can be stored in one memory location. When a half-word instruction in the upper half of the computer word is executed, the processor sets bit 15 of the ASR; if a whole-word or lower half-word is executed the bit is cleared. In the Emulator, this bit determines whether the subroutine IFETCH or HALFFETCH is executed. IFETCH reads the next 32-bit instruction from memory. HALFFETCH shifts the lower half-word of the current instruction into the upper halfword position for execution.

Each of the five formats divide the instruction into different fields. Each field except "y" (the constant or address field) has a particular function in controlling the various internal enables and commands required for proper execution of the instruction. Some fields define the use, modification or application of the y-field to secure the desired operand; others select an accumulator, index, or base register; others select an IOC, define a sub-function code, or combine to form a special interpretation defined by the instruction. The AN/UYK-7 maintains a repertoire of 132 central processor instructions whose specific functions are defined in detail in reference 26.

Bit No.	31--26	25-23	22-20	19-17	16	15-13	12---0
FORMAT I	f	a	k	b	i	s	y
FORMAT II	f	a	f2	b	i	s	y
FORMAT III	f	a	f3/k	b	i	s	y

Bit No. Bit No.	31--26 15--10	25-23 9-7	22-20 6-4	19-17 3-1	16 0
FORMAT IV A	f	a	f4	b	i
FORMAT IV B	f	a	m		

INDIRECT CONTROL WORD FORMATS (Indirect Addressing)

Bit No.	31-30	29-25	24-20	19-17	16	15-13	12---0
	c	w	p	b	i	s	y
	c	c1	unused	b	i	d	

Elements of the word are interpreted as follows:

FIELD	BASIC DEFINITION
f	6-bit function code
f2	3-bit subfunction code
f3	2-bit subfunction code
f4	3-bit subfunction code
a	3-bit accumulator register designator
k	3-bit operand interpretation designator
m	6-bit shift count designator
b	3-bit index register designator
i	1-bit indirect addressing designator
s	3-bit base designator
y	13-bit address displacement/operand designator
c	2-bit control designator
c1	1-bit indirect subfunction designator
w	6-bit character length designator
p	5-bit position indicator for character length
d	16-bit address displacement

INSTRUCTION AND INDIRECT ADDRESS WORD FORMATS [27]

FIGURE III-1

Of particular note to the reader is the K-Field of the Format I instructions. The value of K designates whether the operand to be fetched/stored is a whole, half, or quarter-word operand, as depicted in Figure III-2. If the value of K implies a partial-word operation, then it also determines which portion of the 32-bit word is to be accessed. That is, a K-value designating a quarter-word (byte) transfer can also specify that the byte is located in the upper, lower, or one of the intermediate two bytes of the 4-byte, 32-bit operand. It is this function that makes the AN/UYK-7 an extremely powerful word processing machine. This function was fully implemented and tested in the Emulator.

K	READ MEMORY to ARITHMETIC	STORE ARITHMETIC to MEMORY
0	sy(SE)+B(b) -> A15-0(SE)	NOT USED
1	Y15-0 -> A15-0 (SE)	A15-0 -> Y15-0;Y31-16 unchg
2	Y31-16 -> A15-0 (SE)	A15-0 -> Y31-16;Y15-0 unchg
3	Y31-0 -> A31-0	A31-0 -> Y31-0
4	Y7-0 -> A7-0 (ZE)	A7-0 -> Y7-0;Y31-8 unchg
5	Y15-8 -> A7-0 (ZE)	A7-0 -> Y15-8; Y31-16 unchg Y7-0 unchg
6	Y23-16 -> A7-0 (ZE)	A7-0 -> Y23-16;Y31-24 unchg Y15-0 unchg
7	Y31-24 -> A7-0 (ZE)	A7-0 -> Y31-24; Y23-0 unchg

SE--sign extended; ZE--zero extended
A is the ACCUMULATOR specified by the a-field

FORMAT I INSTRUCTION K-FIELD INTERPRETATION [27]

FIGURE III-2

D. MODES OF OPERATION

There are several different modes of operation of the AN/UYK-7; most of them are concerned with different addressing techniques. Specifically, they are: normal mode, index mode, repeat mode, and indirection. In the normal mode, the Y-Operand address is calculated as the sum of: the y-offset, a base register and an index register, or Y=y+B(b)+S(s). There are two exceptions to this general formula. First, if the K-field of Format I instructions is a zero then Y=sy+B(b), where "sy" is the concatenation of the s-field and y-field of the instruction. Second, for all instructions regardless of Format, if the B-field is zero then the B(b) value used in calculating the Y-Operand address is always zero. There are several additional addressing techniques employed during the repeat and indirect modes of operation. They are described in detail in Chapter V. These ad hoc addressing techniques employed by the AN/UYK-7 greatly enhance its capabilities but were extremely difficult functions to emulate.

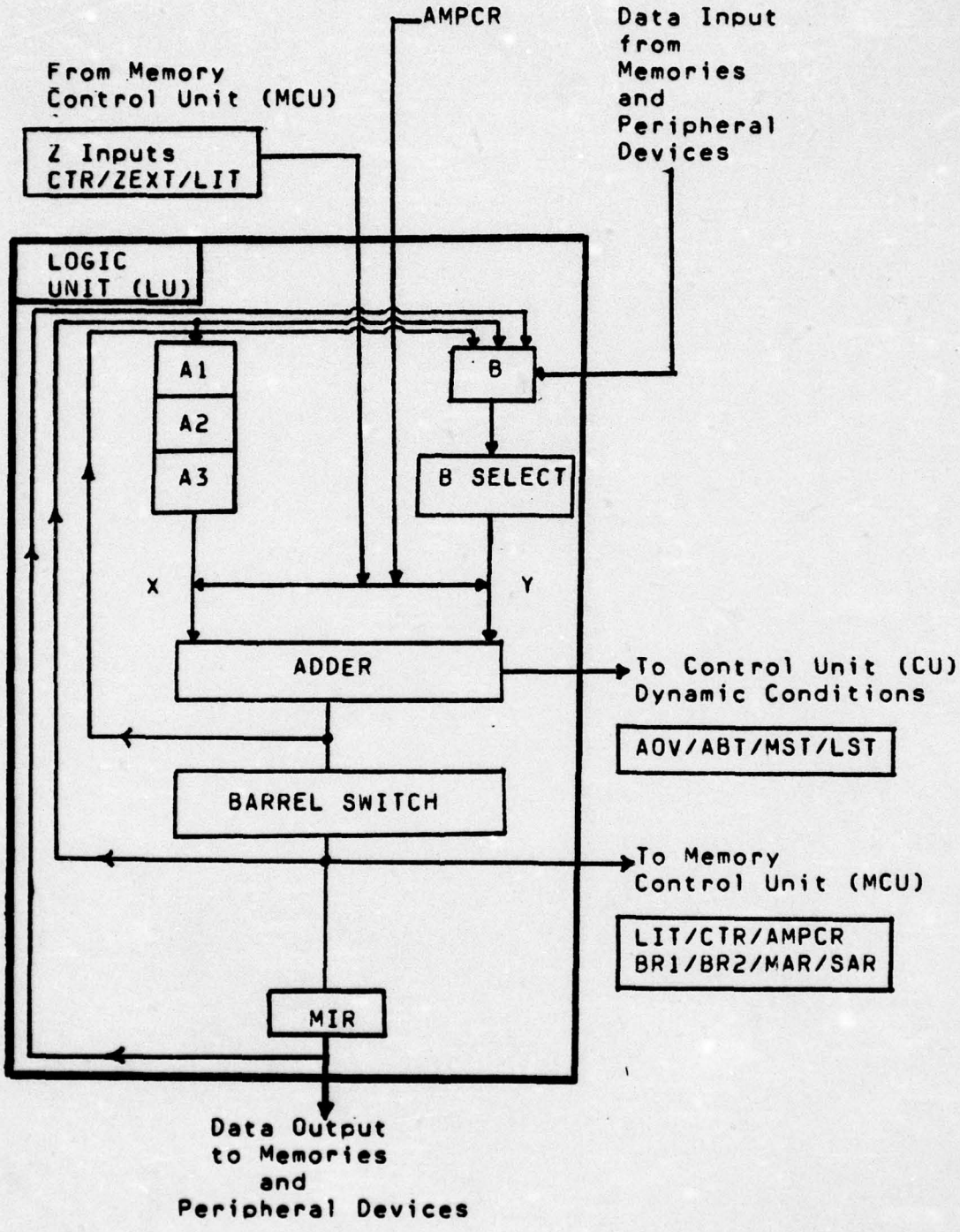
IV. BURROUGH'S D-MACHINE

A. GENERAL DESCRIPTION

An Interpreter Based System is a digital processing concept developed by Burrough's Corporation, that utilizes hardware building blocks which can be tailored through microprogramming to perform as a variety of general purpose or special purpose general processors [7, 8, 24]. The basic Interpreter, also referred to as the D-Machine, is the primary building block of this unique system. It is composed of five functional modules each of which can be modified to manipulate an 8 to 64-bit word format in increments of 8 bits. In the Naval Postgraduate School configuration, two of these modules, the Nanomemory and the Micromemory, are combined into one. The register sizes given in the following descriptions of the modules are specific to this configuration which is a 32-bit D-Machine.

1. Logic Unit (LU)

The Logic Unit (LU), presented in Figure IV-1, contains all the registers, the Barrel Switch and the Adder which are available to the microprogrammer for manipulating data fields during the process of emulating an instruction. A description of each of these registers and its functions follows [8,24].



LOGIC UNIT (LU) BLOCK DIAGRAM

FIGURE IV-1

The 32-bit registers A1, A2, and A3 are functionally identical. They temporarily store data within the Interpreter and serve as the primary (X) input to the adder. Any A-Register can be designated as a destination for the output from the Barrel Switch.

The 32-bit B-Register is the primary external input interface (from the Switch Interlock). It also serves as the secondary (Y) input to the Adder, and can receive the output of the Adder, in addition to the Barrel Switch which is the normal source for the results of arithmetic calculations. The B-Register can be the destination of any of the following during execution of any one microinstruction:

a. The Barrel Switch output.

b. The Adder output.

c. The external data from the Switch Interlock.

d. The Memory Information Register (MIR).

e. The carry complements of four-bit or eight-bit groups.

f. The Barrel Switch output ORed with b, c, or d above.

The output of the B-Register has true/complement selection gates which are controlled in three separate sections: the most significant bit (MSB), the least significant bit (LSB), and all the remaining internal bits. Each of these parts is controlled independently, and may be either all one's, all zero's, the true contents or the one's complement of the respective bits of the B-Register.

The 32-bit Memory Information Register (MIR) buffers the information which is to be written to main system S-Memory, or to a peripheral device. It is loaded from the Barrel Switch output and its output is directed either to the Switch Interlock or the B-Register.

The 32-bit Adder in the LU is a modified version of a straightforward carry look-ahead adder. Inputs to the Adder are from selection gates which allow various combinations of the A, B, and Z inputs. The A input is from the A-Register output selection gates and the B input is from the B-Register true/complement selection gates. The Z input is an external input to the LU and can be:

a. The output of the counter in the Memory Control Unit (MCU) into the most significant eight bits with all other bits being zeros.

b. The output of the literal register in the MCU into the least significant eight bits with all other bits being zeros.

c. An optional input into the middle bits with the most and least significant bytes being zeros.

d. All zeros.

There are always two inputs to the Adder referred to as the X-input and Y-input. An X-input may have A, Z, or zero as its source. A Y-input may have B, Z, or one as its source. An unspecified X-input is always assumed to be zero. Using various combinations of the possible inputs to the selection gates, any two of the three (A, B, or Z) inputs can be added together, or can be added together with an

additional one added to the least significant bit. In addition, all binary Boolean operations can be performed between any two inputs.

The 32-bit Barrel Switch is a matrix of gates that shifts a parallel input data word from the Adder, any number of places to the left or right, either end-off or end-around. The output of the Barrel Switch may be gated to one or more of the following simultaneously:

a. The A-Registers (A1, A2, A3).

b. The B-Register.

c. Memory Information Register (MIR).

d. Least significant 16 bits of MCU registers (BR1, BR2, MAR, AMPCR, CTR).

e. Least significant 5 bits to the Control Unit (CU) for the shift amount register (SAR).

2. Memory Control Unit (MCU)

One MCU is required for an Interpreter to have access to 64K of main memory [8, 24]. The addition of a second MCU is possible, thus expanding on-line memory access to 128K. The MCU has three major sections:

a. The microprogram address section contains a microprogram count register (MPCR), the 12-bit alternate microprogram count register (AMPCR), the incrementer, the microprogram address controls register, and their associated control logic. This section is used to address the Microprogram Memory (MPM) for the sequencing of microinstructions. The AMPCR contents may be used as a Y-input to the Adder.

b. The memory/device address section contains the 8-bit memory address register (MAR), the two 16-bit base registers BR1 and BR2, the output selection gates, and their associated control logic.

c. The Z register section contains registers which are the Z inputs to the LU Adder: a loadable counter (CTR), the literal register (LIT), selection gates for the loadable counter and their associated control logic.

3. Control Unit (CU)

The Control Unit (CU) has five major sections: the shift amount register (SAR), the condition register (COND), part of the control register (CR), the MPM content decoder and the clock control [8, 24].

The functions of the SAR and its associated logic are:

a. To load shift amounts into the SAR for use in (0 to 32-bit) shifting operations.

b. To generate the required controls for the Barrel Switch to perform the shift operation indicated by the current microinstruction.

c. To generate the "word length complement" of the SAR contents, where the "complement" is defined as the amount that will restore the bits of a word to their original position after an end-around shift of N followed by an end-around shift by the "complement" of N.

The control register (CR) is a 56-bit register that stores all those control signals from the current microinstruction which are not used in phase I. The CR is divided into the phase III controls and the MPAD controls.

The condition register (COND) section of the CU performs four major functions:

a. Stores 12 resettable condition bits in the condition register. The 12 bits of the condition register are used as interrupts, error indicators, status indicators, and lockout indicators.

b. Selects 1 of 16 condition bits; 12 from the condition register and 4 dynamically generated during the present clock time in the Logic Unit for use in performing conditional operations.

c. Decodes bits from memory for resetting, setting or requesting the setting of certain bits in the condition register.

d. Resolves priority among Interpreters in the setting of global condition (GC) bits which provide a facility for inter-Interpreter lockout control.

4. Microprogram (M-Memory)

The Micromemory (M-Memory), also known as the Nanomemory (N-Memory) in the Naval Postgraduate School configuration, is a programmable control store memory which contains the user supplied microprograms in the form of microinstructions. Each microinstruction consists of a 56-bit nanoinstruction and provides the gating for functioning of the previously discussed LU, MCU, and CU modules. Micromemory consists of two 4K, 56-bit, modules allowing the

programmer access to approximately 8K of control store. The sequencing of microprogram instructions is controlled by the following procedure: the Nanomemory provides information to the condition testing logic indicating which condition is to be tested. The condition testing logic provides a TRUE/FALSE signal to the successor logic which selects between the three TRUE and three FALSE successor bits. These three successor bits provide eight possible successor command combinations which are listed below with their associated interpretations:

a.	WAIT	Repeat the current instruction
b.	STEP	Step to the next Instruction
c.	SKIP	Skip the next instruction
d.	JUMP	Jump to address in AMPCR
e.	RETN	Return from a micro subroutine
f.	CALL	Call a micro subroutine
g.	SAVE	Save the address of the head of a loop.
h.	EXEC	Execute one instruction out of sequence.

The particular successor command specified then provides the controls needed in the selection (MPCR/AMPCR) and incrementing logic to generate the next MPM address. Except for the EXEC command the MPCR is loaded with the MPM address.

For a more thorough description and discussion of these five modules, reference 10 provides an outstanding

diagrammatic breakdown of the Interpreter's internal hardware configuration and operation. Reference 7 discusses the interface of various Interpreter, peripheral, and memory configurations that have been tested by the Advance Development Organization of Burrough's Defense Space and Special Systems Group.

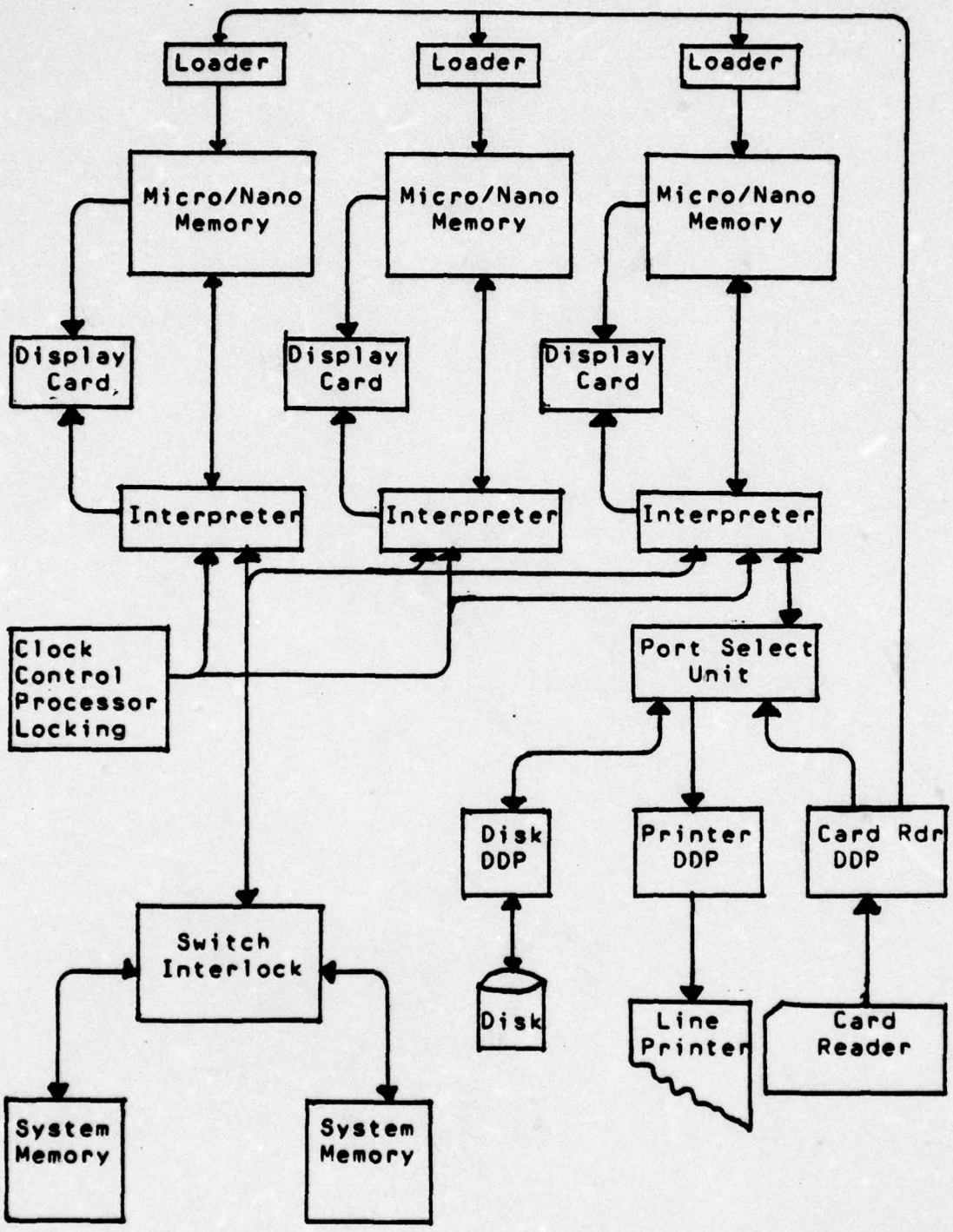
In general, there are three data processing functions to which the Interpreter may be applied: emulation of existing or hypothetical machines; direct execution of high level languages; and problem solution through microprogram "tuning" of the machine to the problem. The initial goal for the installation at the Naval Postgraduate School is emulation of existing machines such as the AN/UYK-7, with further expansion and development as a teaching tool in the areas of operating systems, file management, compiler writing, and emulation of hypothetical systems.

B. NAVAL POSTGRADUATE SCHOOL CONFIGURATION

1. Description

The system presently installed at the Naval Postgraduate School consists of three Interpreters, one 64K memory module, a card reader, line printer and dual cartridge disk. Only one of the three Interpreters is allowed to communicate directly with any peripheral and is discussed below under I/O Interface. Figure IV-2 represents the present configuration; however, future expansion calls for the addition of a supervisor's console and a cross-connection with the school's PDP-11/45. This will enhance the attached peripherals by three tape drives and greatly increase the amount of on-line storage to the point where implementation of a CMS-2 Compiler may be feasible.

When the system is energized and initialized daily, its basic microstructure is that of two B-6700 LIFO ALGOL Stack Machines - each with 32K of memory - attached to a single Input/Output Processor. The system is capable of pseudo-multiprocessing in this configuration. ALGOL programs submitted through the card reader are executed in a batch mode with the two processors competing to fetch the next job. All utiltiy programs, the operating system and the file manager are executed with the machine in this configuration. In order to change the machine's configuration, the user must alter the microcode in order to execute the desired machine such as, the AN/UYK-7.



NAVAL POSTGRADUATE SCHOOL THREE INTERPRETER SYSTEM

FIGURE IV-2

2. I/O Interface

Since only one Interpreter (IOP) is allowed to exchange data directly with the peripherals, it is necessary for the remaining two processors to communicate their I/O requests to the IOP. This is done by the Interpreter placing a message in address 64K otherwise known as the "Mailbox", and then issuing an interrupt (INT) to the IOP. The IOP periodically tests for INT and when sensed, reads the Mailbox, decodes the message, and performs the predefined function. After completing its task, the IOP places a message in the Mailbox informing the requesting Interpreter whether or not the I/O was performed successfully. The IOP then issues an INT to the Interpreter which sent the request. When the requesting Interpreter receives the INT, it reads the Mailbox to determine whether its request was performed and continues accordingly. This method allows the two Interpreters to act completely independently, each referencing only its assigned segment of memory and the IOP performing all I/O asynchronously upon request.

3. Memory Interface

The memory module consists of a single ported, 64K, 32-bit word, core memory, which is the equivalent of 256K of on-line, 8-bit character storage. Access to this single memory is through a Switch Interlock Unit (SWI) which makes memory appear to be multiported to the user. The SWI acts on a priority basis with that Interpreter having the lowest

number (the IOP) given the highest priority. Once an Interpreter issues a memory read/write reference, it may continue execution and need not wait on a memory completion signal. However, the memory address register (MAR) on a Read/Write, and the Memory Information Register (MIR) on a write, should not be changed until a completion signal is received. Thus a microprogrammer who anticipates his memory accesses and intersperses these instructions among the other code, should never have a delay caused by memory referencing.

C. INSTRUCTION TIMING

The Interpreter uses a one megahertz clock and initiates a new microinstruction every microsecond. The Interpreter enhanced with Emitter Coupled Logic (ECL) and a higher speed memory can operate off an 8 Megahertz clock. A corresponding 8-fold improvement in execution times can be expected.

There are two basic instruction types in the Interpreter. Type I uses two phases (I and III) for execution; although, its phase III may be held in abeyance until completion of a subsequent Type II, which always uses only phase I to complete. Phase I of the following Type I instruction always overlaps Phase III of the previous Type I. Type I instructions involve condition testing, external functions and Adder/Logic operations. Type II instructions involve literal assignments to one of three registers (LIT, SAR and AMPCR). Appendix D of reference 9 contains an excellent discussion of instruction timing.

D. LANGUAGES

The D-Machine has two resident programming languages: the language of the operating system, ALGOL; and the microprogram assembly language, TRANSLANG.

1. ALGOL

The resident programming language of the Burrough's D-Machine is the ALGOL 60 Language enhanced with additional language constructs which permit manipulation of data in the form of character strings. ALGOL employs a vocabulary of reserved words and symbols. The structure of the language, syntax, reserved words and symbols, and additional features of the ALGOL implemented on the D-Machine are discussed in reference 10. The accepted character set for ALGOL varies depending on the machine used and the character set or sets available on the machine. The Naval Postgraduate School configuration requires that all characters be converted from EBCDIC into the 6-bit Burrough's Common Language (BCL) format for recognition by ALGOL. This conversion is performed by the IOP when it is used for interfacing communications from external devices to the other Interpreters. When information is directed to an external device the IOP performs a reverse conversion, from BCL to ASCII. Thus all inputs to the emulator from peripherals are 8-bit characters containing a 6-bit BCL code. The Interpreter's file management routines, operating system and utilities are written in ALGOL, for execution on the ALGOL Stack Machine

configuration. ALGOL source modules may be inputted to the ALGOL Compiler from disk or cards. Object modules are placed in user libraries on disk for future execution by the stack machine. The operating system (MCP) will load specific object modules for execution when it recognizes a "?RUN filename" control card, where filename is assumed to be a precompiled ALGOL program.

2. TRANSLANG

The microprogrammer is aided in producing microprograms by a Microtranslator/Assembler that translates symbolic instructions written in TRANSLANG into microinstructions. Reference 9 describes the structure of TRANSLANG by defining its syntax and semantics, and presenting a series of examples. The reference also includes descriptions of register state changes resulting from executing microinstructions. Interpreter controls and timing are explained. Coding techniques and conventions are discussed via sample programs. The reference analyzes external operations with main memory and peripheral devices, and the coordination and control of multiple Interpreters via the Switch Interlock and global condition bits.

The Microtranslator is written in ALGOL for the D-Machine. It is written modularly with each function setup as a procedure call. The language, TRANSLANG, used ALGOL as a model; however, almost the entire language is composed of reserved words. Reserved words have very specific meaning

to the translator and cause specific nanoinstructions to be developed. TRANSLANG is free form and each instruction may be written in almost any order; however, multiple instructions appearing on the same line or card must be separated by a period. Each TRANSLANG instruction corresponds to one microinstruction, which is the set of Interpreter functions performed in parallel at each machine clock. The constructs provided include iterative mechanisms, I/O, Boolean, logical and computational operations, control transfers, and assignment functions. In order to provide control points for transfer operations, each instruction may be labeled with a symbolic M-Address. The output module of the Microtranslator is placed on disk and when loaded into micromemory, alters the basic machine configuration. Reference 9 is used as the microprogrammer's programming manual; although, there have been several enhancements to the machine and language which are not included in the manual. These modifications are discussed in Appendix A of this thesis.

V. PROJECT DESCRIPTION

The AN/UYK-7 achieves its speed and versatility partially through concurrent field utilization and partially through the provision of special and general purpose registers. Its emulation is complicated by the various modes of instruction operation (repeat, indirection, indexing) and in particular by the use of ad hoc addressing techniques. The fact that the AN/UYK-7 performs many of its operations in parallel makes it difficult for an emulation which is imitating one facility at a time to run in AN/UYK-7 real-time. For the remainder of this discussion the acronyms A(a), B(b) and S(s) refer to the Accumulator, Index and Base registers, respectively. The subscripts (a, b, and s) correspond to the register specified in the cognizant field of the instruction, and may assume values of 0 to 7. Capitol "Y" refers to the effective 18-bit, operand address; small "y" refers to the 13-bit, y-field of the instruction. The combination sy-field is formed by concatenation of the 3-bit, s-field and 13-bit, y-field of the instruction and forms an alternate operand address.

During the initial analysis of the Emulation it was decided to separate the project into the following phases:

First, the machine would be designed to accommodate a full emulation including multiprogramming and all IOC

functions. This required that all registers and condition bits of the actual AN/UYK-7 hardware be mapped into the model, even if they would not be used during this partial Emulation.

Second, it was decided to divide the Instruction Repertoire into the following groups:

a. Those instructions that could be emulated immediately and tested completely; such as, all Format I's and II's except Multiply, Divide, Square Root and Double Register Operations.

b. Those instructions that could be done prior to completion but for which there might be insufficient time for complete testing; such as, all Format III's, Shifts, Multiply, Divide, and Double Register Operations.

c. Those special instructions and functional modes that would be incorporated if at all possible; such as, indirection and repeat.

d. Those features for which there would definitely be insufficient time for incorporation; such as, Interrupts, IOC Instructions, and Floating Point Operations.

Third, a "Loader" program which could read AN/UYK-7 instructions from cards, decode them and place the results into memory for execution by the Emulator was mandatory.

Fourth, some facility for monitoring and debugging each instruction as it is executed by the Emulator would be required.

Fifth, some facility to output the results of each AN/UYK-7 program and to input test data was needed.

To accomplish these five tasks, two basic programs called the "Loader" and the "Emulator" were written. Each of these programs occupied its own Interpreter whenever the system was reconfigured as an AN/UYK-7.

A. LOADER

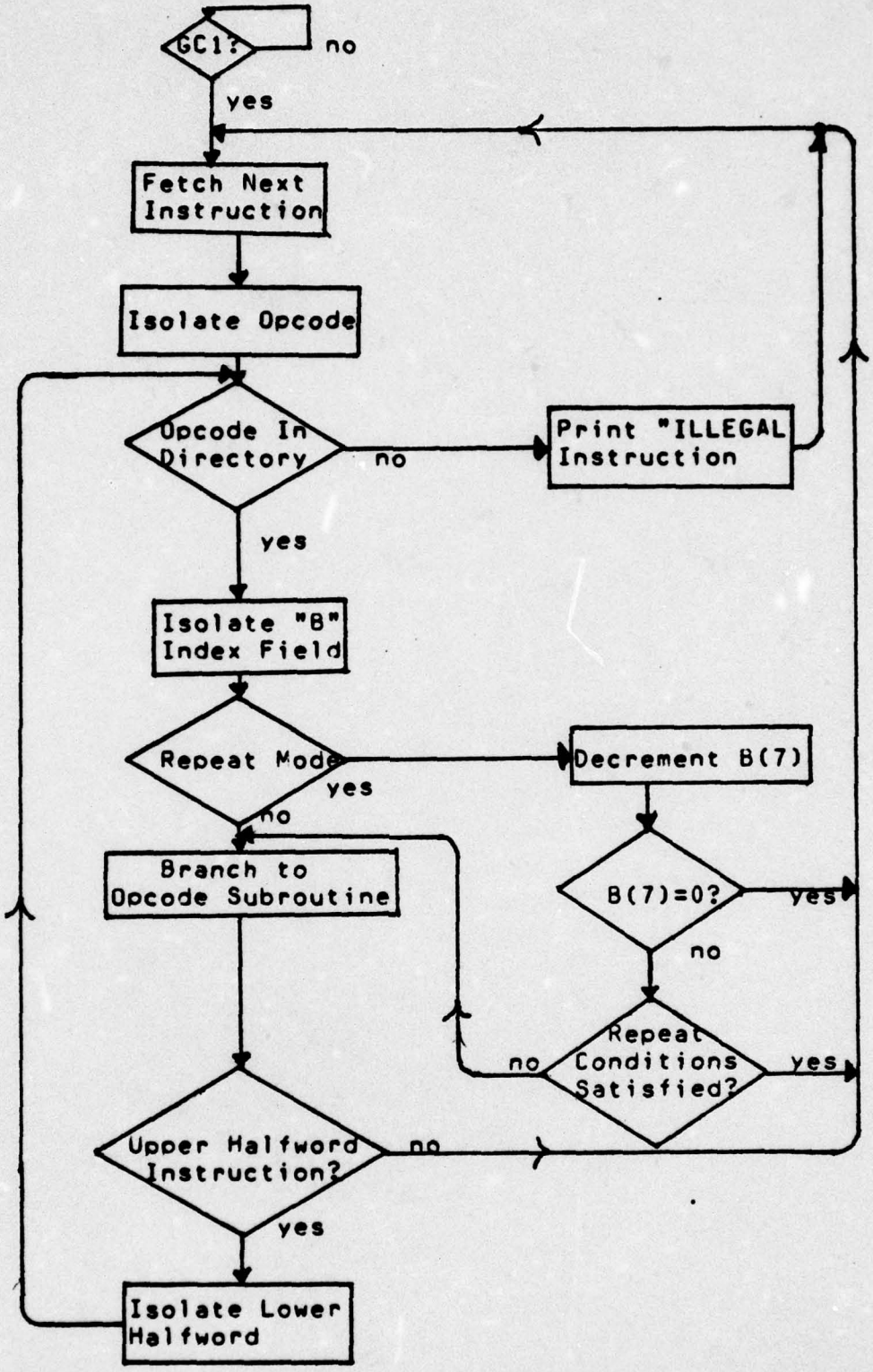
The Loader was written in TRANSLANG and fulfilled the third, fourth and fifth requirements; that is, it served as a combination loader, debugger and IOC monitor. Its use is described in Appendix A, the User's Manual section of this thesis. In general, the loader portion of the program acts like a pseudo-assembler. It has macros for defining a constant or character string, for saving space, for intitializing registers and switches, and for inputting instructions. The loader will accept one instruction per card and determine whether it is a Format (I, II, III, IV-A, or IV-B) instruction. Based on this determination, the Loader will decode the specified fields from the card and generate a binary instruction which is placed in the next sequential location in the user's memory. Upon detecting an "N" card, the loader portion of the program signals the Emulator - which is resident in the alternate Interpreter - that instructions are available for execution.

At this point the loader function ceases and the program can be called upon by the Emulator to act as a debugger or as an IOC. As a debugger, the Loader can be used to generate a number of error messages to the operator, or to provide an actual dump of control memory registers 000 to 035, which includes all Task Registers, the PAR and the Active Status Bits. As an IOC, the Loader can be called upon to read a card, print a buffer, or read the disk.

It should be emphasized that the Loader was written strictly as a tool to assist in the development and testing of the Emulator. Presumably, once a full emulation is written and tested, the IOC functions will be incorporated into the Emulator, while the loader and debugger functions will be either written in AN/UYK-7 Machine Language, or absorbed by the Emulator. When this is done, the Interpreter previously utilized by the Loader will be free for loading as a second AN/UYK-7, and a true multiprocessing environment could be created. A copy of the Loader is provided in Appendix C.

B. EMULATION PROGRAM

The Emulator was written in TRANSLANG microcode, and is loaded directly into the Interpreter's micromemory from disk. A copy of the Emulator is provided in Appendix B. Overall program flow for the Emulator is presented in Figure V-1.



OVERALL PROGRAM FLOW

FIGURE V-1

Besides the necessary Control Memory Register mappings, it was necessary to minimize memory references by maintaining certain frequently used information in the D-Machine's internal registers. For this reason, the PAR is maintained in the lower 20 bits of the D-Machine's A2 register. The upper 12 bits of A2 are used to maintain some of the most frequently referenced bits of the AN/UYK-7's Active Status Register as listed in Table V-1.

ASR Bit	A2 Bit	Function
2	31	Equal/Unequal
1	30	Greater Than/Equal
0	29	Limits
3	28	Fixed PT Overflow
8	27	Task use of 05-4
9	26	Remove Interrupt Lockouts
10	25	Int/Task Accumulators
11	24	Int/Task Base Regs.
N/A	22-23	01 = Indirection 10 = Optional Indirection 11 = Character Addressing
N/A	21	Repeat Mode
15	20	Halfword Indicator
N/A	0-19	PAR

ACTIVE STATUS REGISTER

TABLE V-1

The remaining bits in the ASR are not used in this Emulation, but if needed could be mapped into any unused location in memory below address 1024.

The D-Machine's A1 register is used to maintain a copy of the instruction currently being executed. All other registers are free for computational use. The D-Machine's

General Condition Bit One (GC1) is reserved for communicating with the Loader. General Condition Bit Two (GC2) is used to indicate that an AN/UYK-7 instruction is being executed under a special condition; such as, repeat mode or indirection.

The Emulator consists of an Opcode/Sub-opcode Directory, an instruction fetch routine (IFETCH), global subroutines and opcode execution subroutines. When the Emulator receives a signal from the Loader (GC1) to commence excution, it immediately passes control to IFETCH, which reads the PAR and places the first instruction in A1. The opcode portion of the instruction is isolated and used as a pointer into the Opcode Directory. Control is then passed to the opcode execution subroutine designed to handle that particular instruction. The opcode subroutines may stand alone and perform their functions independently; or they may call several global subroutines used to consolidate code for multiple opcodes. Upon completion of its execution, the opcode subroutine passs control back to IFETCH which then fetches the next instruction.

In the case of halfword instructions, control is passed to HALFFETCH which serves the same purpose as IFETCH, except for 16 bit instructions. Every attempt is made within the opcode subroutines to do in-line coding versus subroutine calls. This decreases execution time considerably; although, it greatly increases program size. During the initial programming phase the Interpreters were limited to a

4K micromemory due to the dynamic overlay routine (SMX) being positioned at 4k. As a result, excessive subroutine calls were necessary in order to keep the program size below 4K. This software deficiency has since been corrected by Burrough's and a full 8K micromemory is now available. These subroutine calls could now be removed and the subroutines moved back in-line.

Emulation of Central Processor instructions in the AN/UYK-7 repertoire was fairly straightforward. Most instructions were implemented with an average of 15 microinstructions. This generally included: isolating the various fields, forming the effective operand (Y) address, fetching the operands from main memory, performing the instruction function, and writing the result back to main memory, commonly referred to as S-Memory. Because of the parallelism of the D-Machine's nanoinstructions several of these functions were performed simultaneously. Many AN/UYK-7 instructions have sub-opcodes, each of which perform a different operation on the same operands. In such cases, the opcode subroutine centralized code by performing the field isolation and operand fetch functions prior to calling the sub-opcode subroutine. Either the operand itself or its address was passed in a register to the subroutine, which then performed its function and wrote the results back to S-Memory.

The difficulties arose in the AN/UYK-7 Emulation when the repeat and indirection modes of operation were implemented. The Repeat Instruction required that the next

sequential instruction be executed the number of times contained in the Index Register B(7), or until specified alternate conditions were met. This required that flags be set indicating that the repeat mode had been initiated and that special termination conditions were to be tested. Condition testing took place after each execution of the repeated instruction and prior to return to IFETCH for the next instruction. If the conditions were not satisfied IFETCH was bypassed and the same instruction was reexecuted after first decrementing B(7), and then indexing the operand address by the displacement value contained in the repeat instruction. If the conditions were met the normal IFETCH mode was executed and the repeat mode was terminated. Most instructions required checking the condition of a specified accumulator register to signal completion of the repeat mode; however, compare instructions used the results of their comparison to signal completion. Repeated replace instructions used a different Y-operand calculation for their store phase then for their fetch phase. Instructions that were not designated as being repeatable were executed once and the repeat mode was terminated. A copy of the Repeat Instruction was saved in S-Memory at address 0030; a copy of the instruction being repeated was saved at address 0031; and the Y-operand address used for storing during a repeated replace instruction was saved at 0033. These addresses are given in octal and are normally unused in the AN/UYK-7.

The indirect modes of operation possible in the AN/UYK-7 were extremely difficult to emulate. There are four modes of indirection possible: Normal Indirection, Character Addressing, Sequential Character Addressing, and Optional Indirection. Not all instructions are indirectable and some instructions are indirectable but not character addressable. To make this determination a table was created in the Emulator which would return a value based on the instruction opcode. This value indicates whether an instruction is repeatable, indirectable, or character addressable. All modes of indirection are initially signalled by the i-field of the instruction being a one. This indicates that the Y-operand points to an Indirect Control Word (ICW). The ICW, which is presented in Figure III-1, is then fetched and its bits 30-31 are examined to determine the indirection mode. In all cases, if the i-field of the ICW is set, the Y-operand again points to a new ICW. The Y-operand is calculated in accordance with the indirect mode. Operand fetching will continue in this manner, cascading through memory, until an ICW is found without its i-field set. At this point the lower 20 bits of the ICW replaces the lower 20 bits of the original instruction.

Normal indirection is indicated by a binary 10 in bits 31-30 of the ICW. Y-operand address calculation is performed as Y=y+B(b)+S(s). Once the final ICW is determined then normal execution of the instruction resumes.

Single Character Addressing is indicated by a binary 01 in bits 31-30 of the ICW. Y-operand address calculation is performed as Y=y+B(b)+S(s); however, in this mode two additional fields (P,W) of the ICW are meaningful. The P-field indicates the least significant bit position of the character to be fetched from the operand and the W-field indicates the number of bits in the character. When the character is fetched - it is right justified; operated on in accordance with the instruction; and then (depending on the instruction) ORed back into its original position in the Y-operand.

Sequential Character Addressing indicated by a binary 11 in bits 31-30 of the ICW, operates in exactly the same manner as Single Character Addressing except in the case where the store cycle is required. Before ORing the resulting character back into the Y-operand the P and W-fields are compared. If P minus W is positive then the difference replaces P and the character is stored accordingly. If the difference is negative then 32 minus W replaces P and the "sy" field of the ICW is incremented by 1 and replaced in memory for the next execution.

Optional Indirection is indicated by a binary 00 in bits 31-30 of the ICW. In this mode bit 29 of the ICW is also significant and modifies the Y-operand address calculation. If bit 29 is 0 then Y=sy+S(b). If bit 29 is 1 then Y=sy+B(b)+(S), where S is designated by bits 17-19 of B(b). Once the first operand is fetched then normal instruction execution occurs.

A large portion of the Emulation code was devoted to handling the four modes of indirection and its ad hoc address calculations. General Condition Bit 2 (GC2) was used to flag the indirect and repeat modes of operation. Address 0032, octal, in S-Memory was reserved for saving the current ICW being used during Character Addressing; address 0033, octal, was reserved for the Y-operand address in the case of optional indirection; address 0034, octal, was reserved for the address of the current ICW which could be updated during sequential character addressing. These addresses are part of the Control Memory Registers and are not normally used in the AN/UYK-7.

Although the IOC has not been emulated, Input/Output functions were implemented which make the systems' peripherals accessible to the user. The AN/UYK-7 Initiate I/O instruction was implemented in the Emulator with the exception that the a-field, which is normally used as a channel designator, actually designates the desired peripheral. Based on the contents of the a-field, a function code is formulated and passed to the IOC portion of the Loader. The Emulator then enters a neutral state awaiting an Interrupt from the Loader that the I/O has been performed. The Y-operand address of the I/O instruction fetched by the Emulator points to the address of the buffer, rather than to a buffer control word as in the AN/UYK-7. It was felt that

implementation of I/O in this manner would remain virtually transparent to the user, and would facilitate full emulation of IOC functions at a later date.

Of the 132 instructions in the AN/UYK-7 Repertoire, 111 have been fully implemented and tested. One instruction (Return Jump) has been implemented but not tested. Twenty instructions remain to be both written and tested. All unwritten instructions were assigned space in the Opcode Directory and, if used by the programmer, will cause an error message to be printed to the effect that the instruction has not been yet implemented. The implementation of these instructions involves developing the required microcode and inserting it into the space already allocated in the Opcode Subroutine Library. The unimplemented instructions include all Floating Point Operators, Scale Factor, and Interrupt Handlers.

The Repeat Instruction and its associated mode of operation have been implemented and tested with the exception of the repeat replace instructions, which have been written but not yet tested. Indirect addressing has been fully implemented but has not been tested. Input/Output functions of the IOC have been implemented and tested allowing the user to read a card, print a buffer, or read a disk sector. The disk write function has been designed into the Emulator but not implemented for fear of destroying resident disk material during execution. This function should not be fully employed until either a monitor system is developed which

would preclude write access to assigned disk sectors, or the assumption is made that the entire disk is available to the user as a scratch pad.

C. REGISTER MAPPING

Because the D-Machine has few registers available to the user, the authors chose to map all of the AN/UYK-7 registers into main memory. In addition, it was necessary to create several special locations to hold temporary results or conditions. In order to facilitate this mapping, all memory locations below 1024 decimal are reserved; thus, all user instructions and memory references were offset by this amount by the Loader. Since this Emulation will be in a monoprogramming environment, all Base Registers were initialized in increments of 8K with the first Base Register set to 1024. This allowed user access to approximately 63K of main memory, with each Base Register referencing an 8K page of memory. The Control Memory Register (CMR) allocations and additional temporary mappings (indicated by an *), are presented as part of Figure V-2. The registers marked "*" are not used in the AN/UYK-7, and were thus assigned special purposes in the Emulator. Additional unused register areas are available and labelled "unused" in Figure V-2. These register areas could be employed for the same purposes if needed in the course of expansion to a full emulation.

OCTAL ADDRESS	DECIMAL ADDRESS	DESCRIPTION
0-7	0-7	Task A-Reg. (0-7)
10	8	Unused
11-17	9-15	Task Index B-Reg. (1-7)
20-27	16-23	Task Base S-Reg. (0-7)
*30	24	Repeat Instruction Temp.
*31	25	Current Instruction being Repeated
*32	26	Current Indirect Control Word (ICW)
*33	27	Y-operand for Indirection
*34	28	ICW Address in Memory
*35	29	Program Address Register
36-57	30-47	Unused
60-67	48-55	Interrupt Breakpoint Registers (0-7)
70-77	56-63	Active Status Words (0-7)
100-107	64-71	Int. A-Registers (0-7)
110	72	CP Monitor Clock
111-117	73-79	Int. Index B-Reg. (1-7)
120-127	80-87	Int. Base S-Registers (0-7)
*130	88	Switch Values Temporary
131-137	89-95	Unused
140-157	96-103	Designator Storage Words (DSW)
160-167	104-111	Storage Protection Registers (SPR)
170-177	112-119	Segment Identification Registers (SIR)
*200	120	Location Counter
*201	121	Real Time Clock
*202-246	122-166	Disk Input Buffer
*247-323	167-211	Disk Output Buffer
*324-357	212-231	Card Input Buffer
360-365	232-237	Unused
*366-426	238-270	Printer I/O Buffer
427-437	271-279	Unused
*440-1777	280-1023	Error Routines
2000-77775	1024-65533	User Program Area
*77775-77776	65534-65535	Mailbox

*-Temporary Location Established By Programmers Convention

REGISTER - MEMORY MAPPING

Figure V-2

D. TIMING

Although no formal timing survey was conducted, an analysis of the Emulation itself provided an indicator which was used in developing a comparison to real-time. For this analysis it was assumed that each instruction was executed using direct addressing and not in repeat mode. The IFETCH routine used 16 microseconds which was an automatic overhead acquired by all instructions. The operand fetch and store routines (YFETCH, YSTORE and Y2FETCH) added an additional 33, 30, or 14 microseconds, respectively. Thus any instruction which referenced a Y-operand incurred an additional overhead of 14 microseconds at a minimum. Adding to this overhead, the execution time of the basic opcode itself yielded the time estimated for typical instructions given in Table V-2.

INSTRUCTION TIME	OPERANDS	EMULATION TIME	AN/UYK-7 TIME
Load	Register,Y	60	1.5
Add	Register,Y	63	1.5
Add	Register	36	1.0
Divide	Register,Y	600	15

TIME ESTIMATES

TABLE V-2

Using these figures it was estimated that this Emulation ran on the order of 40 times real-time. Two steps could be taken that would considerably improve this time. First, move all out-of-line subroutine calls in-line in the opcode subroutines. Second, enhance the Interpreter as discussed under Instruction Timing in Chapter III. It has been estimated that this same Emulation could run at approximately 5 times real-time on an enhanced D-Machine. This time compares favorably with a Simulation of the AN/UYK-7 written in PL-360 for the IBM 360, which runs on the order of 1000 times real-time. As discussed in Chapter II, it would be difficult to approach real-time in emulating the AN/UYK-7 because of the parallelism of its fetch and field isolation operations. The addition of a Field Select Unit (FSU) and additional internal temporary registers would be required before a real-time emulation could be realized.

VI. SUMMARY

The authors' conclusions and recommendations resulting from any research project are a fundamental part of the formal presentation and are therefore included in this thesis. In addition, the authors felt that the reader, who might be contemplating an emulation project, would be interested in the problem areas encountered during the pursuit of this thesis. Accordingly this chapter is divided into two sections - Problems and Conclusions.

A. PROBLEMS

During the course of this emulation numerous software and hardware problems were encountered which had a considerable effect on progress and the amount accomplished in the allocated time. Software problems stemmed principally from poor documentation of the D-Machine, the AN/UYK-7, their associated languages and internal configuration. The software problems with the D-Machine were generally resolved through experimentation on the machine or through phone calls to Burrough's Advanced Development Organization (ADO). The lack of thorough AN/UYK-7 documentation proved to be a more severe handicap since no test base for experimentation was accessible at the Naval Postgraduate School. Such a medium is absolutely mandatory when working in the emulation

environment. The programmer must be able to determine the machine reaction to unorthodox instruction configurations. Some degree of assistance was provided by the Fleet Combat Director Systems Support Activity (FCDSSA), San Diego; however, in some cases the result was a "best guess" as to what the AN/UYK-7 response would be.

Hardware problems are to be expected during the course of any major project and particularly when a new machine is involved. This Emulation was the first project to be undertaken on the Naval Postgraduate School's D-Machine since the machine was installed. The estimated mean-time-between-failures (MTBF) experienced by the authors was less than five hours. Problems ranged from loose circuit boards and dirty contacts, to disk read/write head misalignment. Unfortunately, the time to repair was aggravated by the fact that the school has no technicians trained on the D-Machine, and the authors were inexperienced in its maintenance and operating procedures. Without the assistance provided by Burrough's ADO the project could not have been seen through to fruition. The ADO provided the school with engineering assistance on three separate occasions, the last of which uncovered a major design problem. The machine has since been modified and the system is presently very reliable.

In addition to these two major problem areas progress was inhibited by the following:

1. Lack of Software Utilities - Since the D-Machine was a new installation the school has not had the opportunity to generate the numerous desirable software utilties. In an effort to eliminate the inherent slowness of a "Card Only" system, the authors have undertaken the implementation of the supervisor's console as an adjoint to this thesis. The authors are also implementing a Text Editor which will allow for on-line program modification, and will replace the present card input Line Editor.

2. Microprogramming is not a new concept at the Naval Postgraduate School; however, actual experience was lacking. The Computer Science Department has played a major role in implementation of the D-Machine and the required expertise is rapidly being developed.

3. The learning curve for undertaking an emulation is tremendous. The target machine, the host machine, their respective programming languages and internal configurations must be learned and understood in minute detail.

4. The target machine for this Emulation, the AN/UYK-7, is an extremely sophisticated and difficult to understand computer. The central processor instruction set is fairly straightforward and easy to implement; however, the numerous and differing modes of operation severely complicated the Emulation.

B. CONCLUSIONS

The authors feel that they have successfully achieved their goal of demonstrating the feasibility of emulating the AN/UYK-7 on the Burrough's D-Machine. The design presented in this thesis is a workable design as evidenced by execution of AN/UYK-7 programs successfully and by execution in

less than 40 times the actual execution time of the AN/UYK-7. Better than 90% of the AN/UYK-7 Instruction Repertoire has been implemented and tested, thus providing a sound foundation for a full emulation. The design allows for expansion to a full emulation which would include the IOC instruction repertoire and Floating Point without major modification. Further, the authors have concluded that by modification of the design to place out-of-line subroutine calls in-line and enhancement of the D-Machine, the Emulation would execute within 5 times the actual speed of the AN/UYK-7.

During the course of this project the authors had an opportunity to visit the Naval Surface Weapons Center (NSWC), Dahlgren, Virginia. Emulation in general was discussed with the programming staff, who had just completed emulation of the Trident Computer on the Nanodata QM-1, and who were contemplating emulating the AN/UYK-7 on the QM-2. Based on these discussions, the experience gained in the course of this thesis, and presupposing the present level of knowledge of the authors; it is estimated that a complete emulation of the AN/UYK-7, its IOC and all Interrupt functions would require an additional 2 man years of programming effort. This estimate includes a reasonably sophisticated degree of testing, and assumes full accessibility of the D-Machine and an AN/UYK-7 test base.

VII. RECOMMENDATIONS

The authors feel that this thesis has provided them with a learning experience previously unparalleled in either of their lives, since it has entailed detailed and independent learning of emulation, microprogramming (TRANSLANG), the Burrough's D-Machine and the AN/UYK-7. In addition, the authors became part time technicians in an effort to keep the D-Machine running. It is felt that the same educational horizons await any student considering a similar project; however, in an effort to keep others from having to "reinvent the wheel", the authors have included much of what was learned about these subjects in this thesis. Hopefully, by building on these experiences, others will be able to begin at a much higher level and consequently accomplish more. The following recommendations are submitted for consideration by anyone inclined to undertake a thesis involving emulation.

1. Do no try to emulate a machine that uses hardware interrupts on an Interpreter that does not have interrupts.

2. Pick a target machine that is well defined and documented. Computers are designed to perform a specific set of functions; the results of unorthodox use are not always known, but must be considered by the emulator. The availability of a target machine for testing to determine such results is mandatory.

3. Ensure that the host Interpreter is well documented and has a reasonable set of system utilities; such as, an editor, debugger, simulator, file manager, operating system and compiler.

4. Ensure the host Interpreter will receive hardware support if problems arise.

5. Ensure publications are available covering utilites, hardware, languages and target/host machine capabilities and operation.

6. Be prepared to work independently and have your questions answered through your own experimentation.

In addition to these recommedations, the authors would like to propose several thesis topics applicable to the D-Machine.

1. Several projects could be undertaken as a direct follow on to this thesis:

   a. An Operating System, File Manager, and Assembler could be written in AN/UYK-7 machine language utilizing the existing Emulator.

   b. The present Emulation could be enhanced to include Floating Point and any unimplemented instructions, including incorporation of the IOC functions and allowing for synchronous I/O.

   c. A timing survey could be conducted comparing the existing Emulation with AN/UYK-7 benchmarks.

2. Several thesis projects are possible which entail enhancing the capabilities of the existing D-Machine Installation. These include writing the interface to the PDP-11/45, and a resident Text Editor.

The stand alone environment of the D-Machine lends itself to experimentation with the design of operating systems and file managers.

In summary, the authors would like to state that they found the D-Machine an outstanding learning device in spite of its many hardware problems. The authors found the ability to emulate existing computers exciting, and found the realization that they could build a working model of any computer they could design, exhilarating.

APPENDIX A. USER'S MANUAL

A. D-MACHINE

When the D-Machine was installed at the Naval Postgraduate School, it was not accompanied by any form of documentation for its operation, preventive maintenance, diagnostics or utility programs. For the most part this information has been derived through experimentation and frequent calls to Burrough's ADO. Some of the more pertinent information is included in this User's Manual to enable the user to load and run a program such as the AN/UYK-7 Emulation. Unless specified otherwise all addresses given in this discussion are in hexadecimal.

1. System Initializing

The machine is secured every night and must therefore, be reinitialized when powered up each morning.

a. Ensure circuit breakers 2, 7 and 10 are on.

b. Push the "ON" button on the disc and all three Interpreters.

c. With desired discs in the drives, push the two "RUN" buttons on the disk unit.

d. Turn on the card reader and printer.

e. Place the IOP in normal vice single step mode via the switch inside the cabinet on the right.

f. Push the "LOAD" button on the IOP; then push "CLEAR".

g. Place the cards marked IOP-Loader into the card reader. Cards should be read and the IOP should stop at an MPAD of 00FA. If not, repeat steps e through g.

h. Push the "LOAD" button on IOP to return the IOP to normal.

i. Perform steps e to h for each of the other two Interpreters using the cards marked STK-loader. They should halt at a MPAD of 004A.

k. Push "CLEAR" on each Intrepreter. They should bootstrap themselves through the IOP and halt at either 0542 or 051A. (An Interpreter must be at 0542 to run a program and only one Interpreter can be at 0542 at a time.) Clear the IOP to force an Interpreter to switch from 051A to 0542.

The D-Machine now thinks it is a Burrough's B6700 single-stack machine. Any utility can be run using the proper control cards as documented in the computer lab. The more common utilities are Sunrise (updates the day, date and time; should be run first thing every morning), Dir-List (prints out the directory; system or user), Compile (compiles ALGOL programs) and TRANSLANG (assembles microprograms). By use of the proper control cards, the user can also obtain a source listing of his program as it is being compiled or assembled. Actually the default is a printout every time and the user must insert a "$-list clist" control card to eliminate the listing.

To make the computer act as some machine other than the B6700, use the control card "?SMLOAD filename". The "?" must be in column one and the rest of the card is free-format. This loads the microprogram "filename" (which must be an assembled TRANSLANG program) into micro-memory overlaying the stack machine and then transfers control to that program starting at address 0000. Thus to load the AN/UYK-7, execute "?SMLOAD UYK7-LOADER" on one Interpreter and "?SMLOAD ANUYK7-EMULATOR" on the other. Refer to the appropriate sections of this chapter for further instructions on the execution of these programs.

2. Diagnostics

The programs used for diagnosing hardware problems are written in TRANSLANG and maintained as object modules on cards. The appropriate program is loaded in the same fashion as the bootstrap loader and terminates at a significant address. When "cleared", it should again terminate at an address which indicates success or failure. The operator must determine which from the program listing, as no messages are printed. There are no diagnostics written for the disk, printer or card reader. At the present time a CRT terminal is hooked up to the IOP; however, there is no software support for it. An interface is being written into the operating system and eventually all commands to and from the operator will be via the CRT. The card reader and line printer will then be strictly data I/O ports.

3. Debugging

While executing any TRANSLANG program, the user can monitor the program by use of the nixie light display panel and the function switch assigned to each processor. The lights indicate hex numbers. By selecting the appropriate function the user can observe the current nanoinstruction being executed; the address of the current microinstruction (MPAD); the memory address last written to or read from (BMAR); and the MIR register (MIR and EXT). The MIR function displays the lower 16 bits of the MIR register while the EXT function displays the upper 16 bits. These functions are presently the only means of debugging. For example, if the user were unsure of the information being read from S-memory, he could insert two additional instructions in the code: an instruction to place the data into the MIR register and a "WAIT" instruction. The CPU halts at the "WAIT" instruction and the user can then examine the information in MIR to ascertain its validity. The user may check the MPAD to determine if the address read was actually the address intended. To continue the program the user must press the force-step button inside the side panel. If the user wished to step through a series of instructions following the "WAIT", he could go to single-step, and while holding the force-step button, press the single-step button to override the "WAIT". After passing the "WAIT", single-step to execute one instruction at a time. In this manner the user can debug several instructions one at a time.

B. AN/UYK-7

This section of the User's Manual discusses how the user can reconfigure the D-Machine into an AN/UYK-7.

First, ensure that the disk packs which are mounted are the AN/UYK-7 System Packs and that both interpreters are loaded with an ALGOL Stack Machine.

Second, insert an "?SMLOAD UYK7-LOADER" card in the card reader. This will cause the Loader's microcode to overlay the stack machine's microcode and stop at address "0000".

Third, insert an "?SMLOAD UYK7-EMULATOR" card in the reader. This will cause the Emulator's microcode to overlay the alternate stack machine and stop at address "00A0". The AN/UYK-7 is now ready to accept and execute programs.

Fourth, place the AN/UYK-7 source programs in the reader and force step the Loader and the Emulator, respectively. The Loader will read one card at a time, decode it and place the 32-bit resulting instruction in memory for subsequent execution by the Emulator.

The last instruction of all user programs should be a "HALT", which will cause the Emulator to halt and the Loader to be reinitialized for the next job. Force stepping the Emulator after the halt will cause the next job to be read and executed. Use of this convention permits batch processing of programs by the AN/UYK-7. The program deck organization is discussed in the next section. Individual programs are separated by "N" cards.

1. Loader

a. Macros

This section describes how a program must be keypunched for input to the Loader. All Macro control characters and formats are listed in Figure A-1. Any character typed in column one, which is not listed, will cause an "Illegal Instruction" message and the card will be ignored. It is noteworthy that all functions are optional with the exception of the "N", which must terminate the program deck. All addresses are in octal and considered absolute as far as the user is concerned; however, they are offset by 1024 by the Loader. Macros and instructions may be interspersed as desired.

COL. 1	COL. 4-8	FUNCTION
"A"	Register 0-7	Cols. 9-19 contain the octal value to be inserted in the listed A-Reg.
"I"	Register 1-7	Cols. 9-19 contain the octal value to be inserted in the listed B-Reg.
"D"	Octal Address	Cols. 9-16 contain the decimal value to be inserted at the address listed or in-line if the address=0000.
"R"	Octal Address	Cols. 9-19 contain the decimal number of words to be saved at the address listed or in-line if the address=0000.
"W"	Octal Address	Cols. 9-80 contain the character string to be inserted at the address specified. The string terminates before col. 80 if a single quote (') is encountered.
"S"	Switch Value	Cols. 6-8 contain an octal number whose bit pattern selects which of eight AN/UYK-7 switches the user desires set.
"L"	Octal Address	Causes Base S-Registers to be set at 8K pages starting at 1024, and the program to be loaded at Address.
"O"	Octal Address	Causes change in the program counter in order that subsequent instructions may be loaded at Address.
"N"	Octal Address	Terminates loading of program and initializes PAR to Address for the Emulator.

LOADER MACRO DEFINITIONS

FIGURE A-1

b. Instruction Preparation

For inputting instructions to the Loader three basic formats are used which correspond roughly to the five formats used by the AN/UYK-7. The Loader formats are presented in Figure A-2 under their respective AN/UYK-7 Format Headings. All fields require a right justified octal representation. The "i" field should always be either a one or a zero since it represents a single bit. The combined "F3,K" field of Format III instructions requires that K always be zero; therefore, valid inputs are (0,2,4,6) which correspond to an F3 of (0,1,2,3). Columns 1-3 must always be left blank. Columns 15-80 may be used for programmer's comments. Each instruction is decoded into one 32-bit word and assigned to the next sequential address in memory. However, if the instruction is a half-word instruction then it will be stored in the lower half of the previous word if that word also contained a half-word instruction, else it will be stored in the upper half of the next sequential address. An instruction's sequential address assignment can only be changed via the "O" or "L" macros, which must precede the instruction. A sample program is presented in Appendix D.

FORMAT I

COL 1-3	COL 4-5	COL 6	COL 7	COL 8	COL 9	COL 10-14
BLANK	OPCODE	A-REG	K	B	I	Y-OPERAND

FORMAT II

COL 1-3	COL 4-5	COL 6	COL 7	COL 8	COL 9	COL 10-14
BLANK	OPCODE	A-REG	F2	B	I	Y-OPERAND

FORMAT III

COL 1-3	COL 4-5	COL 6	COL 7	COL 8	COL 9	COL 10-14
BLANK	OPCODE	A-REG	F3,K	B	I	Y-OPERAND

FORMAT IV-A

COL 1-3	COL 4-5	COL 6	COL 7	COL 8	COL 9
BLANK	OPCODE	A-REG	F4	B	i

FORMAT IV-B

COL 1-3	COL 4-5	COL 6	COL 7-9
BLANK	OPCODE	A-REG	SHIFT DESIGNATOR

INSTRUCTION FORMATTING

FIGURE A-2

c. TRANSLANG

Several modifications have been made to the D-Machine and the microprogramming language, TRANSLANG, since the publication of reference 9 in 1970. Unfortunately, an addendum to reference 9 has not been published and these powerful modifications remain undocumented. Because the authors took advantage of these capabilities in writing this Emulation the changes are documented here to provide the user a ready reference. They include: additional logical operators, program address modifiers, and an additional Y-select input register (BMAR).

(1) Logic Operators. The additional logic operators are listed in Table A-1 along with the code generated by the Microtranslator when they are encountered. In the Table, A1 and B are assumed as the X/Y input operands respectively. In addition, listed under the columns labelled TRUE/FALSE, are the tests generated by the Microtranslator when a TRUE/FALSE conditional test is encountered subsequent to the logical operation.

OP	MEANING	CODE GENERATED	TRUE TEST	FALSE TEST
LSS	Less Than	A1-B	NOT AOV	AOV
LEQ	Less Than or Equal	A1-B-1	NOT AOV	AOV
EQL	Equal	A1 EQV B	ABT	NOT ABT
NEQ	Not Equal	A1 EQV B	NOT ABT	ABT
GEQ	Greater Than or Equal To	A1-B	AOV	NOT AOV
GTR	Greater Than	A1-B-1	AOV	NOT AOV

LOGICAL OPERATORS

TABLE A-1

The programmer is cautioned that when the Microtranslator encounters the keywords TRUE/FALSE it backtracks to the last logical operator to determine which test to generate. Thus a TRUE/FALSE conditional test which is arrived at through branching may not have generated the exact code the programmer anticipated. These operators were intended to be used in a sequential fashion as follows:

```
A1 GTR B
If TRUE Then (operation)
```

The Microtranslator generates:

```
A1-B-1
If AOV Then (operation)
```

The following illustrates circumstances in which the Microtranslator does not generate the code expected by the programmer:

```
A1 LSS B
If LC1 Then A1 GTR B;Step Else Skip
If TRUE Then (operation)
```

Generates the code:

```
A1-B
If LC1 Then A1-B-1;Step Else Skip
If AOV Then (operation)
```

In this situation "If AOV" is always generated when the TRUE is encountered; although, obviously if LC1 was not set then the programmer desired to test for "Less Than".

(2) Program Address Modifiers. Two powerful new instructions were added to the D-Machine which allow direct transfer of program control. These are the two Type II instructions: "Label-1=MPCR" and "Label-1=CPCR". The first causes a direct change in the program sequence by loading MPCR with the new Label. The second can be classified as a return jump since it causes a transfer of AMPCR to MPCR, and MPCR+1 to AMPCR; thereby setting up a program jump to a subroutine, and saving the return address. This code is identical to:

```
Label-1=AMPCR
CALL
```

The only difference between them is that the CPCR requires only one instruction for execution, while the CALL requires two instructions.

(3) BMAR. The BMAR register is formed by the concatenation of BR1 or BR2 (16 bits) and MAR (8 bits). It can be used as a Y-Input of 24 bits to the Adder. The actual BR register selected is the one most recently referenced

in an external operation. The user is cautioned in the use of BMAR because of its odd size of 24 bits. The unwary programmer could unintentionally allow extraneous bits in the most significant byte when BMAR is used for temporary storage of 16-bit addresses. That is, the assignment "A1=MAR" is considered to effect a transfer of 16 bits, while in fact 24 bits are transferred. A subsequent statement of "BMAR=A1" could permit extraneous bits to be introduced in the third least significant byte, if the programmer had made the assumption that only 16 bits were involved and automatic masking had taken place. The programmer can force selection of BR1 or BR2 by issuing an ASR or ASE, respectively, prior to a BMAR reference. These are considered external function NOOPS in the Naval Postgraduate School Configuration; however, they may not appear concurrently with a BEX statement.

The remainder of the TRANSLANG statements are reasonably straightforward once the programmer understands the instruction timing idiosyncracies. Reference 9 provides excellent guidance for the novice microprogrammer.

APPENDIX B. EMULATOR PROGRAM LISTING

This appendix provides a copy of the Microtranslator output listing of the Emulator. A copy of the source program is maintained on cards and also on the Burrough's D-Machine disk. The object module produced by the Microtranslator is maintained on disk. Each line of the program is divided into four sections. The leftmost grouping consists of the hexadecimal address to which the microinstruction was assigned by the Microtranslator during assembly. This is followed by the 56-bit microinstruction which was generated. The middle group consists of the programmers' source coding which was input to the Microtranslator. The rightmost group consists of the sequence numbers which were assigned to each input card as it was inserted into the source file on the disk by the Interpreter's resident line-editting program (CARD-LIST).

```
[DNT-32]      TRANSLANG ASSEMBLER   (02/24/76)          TUESDAY  09/28/76   14:26:10

                                $MERGE ANUYK7-EMULATOR
                                PROGRAM ANUYK7-OBJECT                                    00010000
                                ABASE=0                    %ADDRESS OF A-REG(0)          0C020C00 D
                                PAR=29                     %TEMP. STORAGE LOCATION OF PAR 0003CC00 D
                                BBASE=8                    %ADDRESS OF B-REG(0)          00040C00 D
                                SBASE=16                   %ADDRESS OF S-REG(0)          0C050C00 D
                                       S6=22               %ADDRESS OF BASE REG 6        00060C00 D
                                ZERO=0.  ONE=1                                           0007CC00 D
                                CARDBUF=212                %ADDRESS OF PERMANENT CARD BUFFER 0C080C00 D
                                PRINTBUF=238               %ADDRESS OF PERMANENT PRINT BUFFER 0C090000 D
                                RINST=24                   %TEMP. LOCATION OF REPEAT INSTR. 0C10CC00 D
                                CINST=25                   %TEMP. LOCATION OF INSTR. REPEATED 0C110000 D
                                IAW=26                     %TEMP. LOCATION OF CURRENT IAW 0C120C00 D
                                YADDR=27                   %CONTAINS PRECALCULATED Y-ADDRESS 0013CC00 D
                                IAWADDR=28                 %ADDRESS OF CURRENT IAW       0C140C00 D
                                SWITCH=88                  %ADDRESS OF SWITCH VALUES READ-IN 0015CC00 D
0C00  0000 0003 0030 3040              START-1 = MPCR                                    00160C00 D
0C01  0010 000B 0030 00C0              ILLEGAL-1=AMPCR     %INVALID OPR 00               0017CC00 D
0C02  0020 0008 0C30 C0C0              OPR01-1=AMPCR       %INCLUSIVE OR                 0018CC00 D
0C03  0030 0009 0030 C0C0              OPR02-1=AMPCR       %COUNT ONES                   0C19CC00 D
0C04  0040 0008 0030 C0C0              OPR03-1=AMPCR       %REPLACE INCLUSIVE OR         0020CC00 D
0C05  005C 0008 0C30 00C0              ILLEGAL-1=AMPCR     %INVALID OPR 04               00210C00 D
0C06  0060 0009 0030 C0C0              OPR05-1=AMPCR       %DOUBLE LOAD A                00220C00 D
0C07  0070 0003 0C30 00CC              OPR06-1=AMPCR       %FP ADD                       0023CC00 D
0C08  008C 0003 0030 00C0              OPR07-1=AMPCR       %ENTER EXEC STATE             0C240C00 D
0C09  0090 0008 0030 00C0              OPR10-1=AMPCR       %LOAD A                       0025CC00 D
0C0A  00A0 0003 0030 C0C0              OPR11-1=AMPCR       %LOAD A AND INDEX             0C260C0C D
0C0B  00B0 0008 0030 00C0              OPR12-1=AMPCR       %LOAD DIFFERENCE              0C27CC00 D
0C0C  00C0 0008 0030 C0C0              OPR13-1=AMPCR       %SUBTRACT A                   00280C00 D
0C0D  00D0 0003 0C30 C0C0              OPR14-1=AMPCR       %ADD A                        00290C00 D
0C0E  00E0 0008 0030 00CC              OPR15-1=AMPCR       %LOAD SUM                     0030CC00 D
0C0F  00F0 C0C0 0030 00C0              OPR16-1=AMPCR       %LOAD NEGATIVE                0C31CC00 D
0C10  0100 0008 0C30 00C0              OPR17-1=AMPCR       %LOAD MAGNITUDE               0C320C00 D
0C11  0110 0008 0030 00C0              OPR20-1=AMPCR       %LOAD B                       0C330C00 D
0C12  0120 0003 0030 00C0              OPR21-1=AMPCR       %ADD B                        00340C00 D
0C13  0130 0008 0030 00C0              OPR22-1=AMPCR       %SUBTRACT B                   0035CC00 D
0014  014C 0008 0030 00C0              OPR23-1=AMPCR       %STORE B                      00360C00 D
0C15  0150 0008 0030 00C0              OPR24-1=AMPCR       %STORE A                      00370C00 C
0C16  0160 C0C0 0030 C0C0              OPR25-1=AMPCR       %STORE A AND INDEX B          00380000 D
0C17  017C 0008 0030 00C0              OPR26-1=AMPCR       %STORE NEGATIVE               0C390C00 D
0C18  0180 C003 0030 00C0              OPR27-1=AMPCR       %STORE MAGNITUDE              0C400C00 D
0019  0190 000B 0C30 00C0              ILLEGAL-1=AMPCR     %INVALID OPR 3C               00410C00 D
0C1A  01AC 000B 0030 C0C0              ILLEGAL-1=AMPCR     %INVALID OPR 31               00420C00 D
0C1B  01BC 000B 0030 C0C0              OPR32-1=AMPCR       %CLEAR BIT                    00430C00 D
0C1C  01CC 0008 0030 C0C0              OPR33-1=AMPCR       %SET BIT                      0044CC00 D
0C1D  01DC 0008 0030 C0C0              OPR34-1=AMPCR       %REPALCE ADD                  0045CC00 D
001E  01E0 0008 0C30 00C0              OPR35-1=AMPCR       %REPLACE INCREMENT            0046CC00 D
0C1F  01F0 000B 0030 00C0              OPR36-1=AMPCR       %REPLACE SUBTRACT             0C470C00 D
0C20  020C 0008 0C30 00C0              OPR37-1=AMPCR       %REPLACE DECREMENT            0048CC00 C
0C21  0210 0008 0030 00C0              OPR40-1=AMPCR       %MULTIPLY A                   0C49CC00 D
0C22  0220 0008 0030 00C0              OPR41-1=AMPCR       %DIVIDE A                     0050CC00 D
0C23  0230 0008 0030 C0CC              OPR42-1=AMPCR       %COMPARE BIT TO ZERO          00510C00 D
0024  024C 0008 0C30 00C0              OPR43-1=AMPCR       %COMPARE INDEX INCREMENT      00520C00 D
0C25  025C 0008 0030 C0C0              OPR44-1=AMPCR       %COMPARE                      00530C00 D
0C26  026C 0008 0030 C0C0              OPR45-1=AMPCR       %COMPARE LIMITS               0C54CC00 D
0C27  0270 0008 0C30 00C0              OPR46-1=AMPCR       %COMPARE MASKED               0C55CC00 D
0C28  028C 0008 0C30 00C0              OPR47-1=AMPCR       %COMPARE GATED                0C560C00 D
0C29  0290 0008 0030 00C0              OPR50-1=AMPCR       %JUMP ON EVEN PARITY          C057CC0C D
```

```
002A  02A0 0000 0000 00C0          OPR51-1=AMPCR          $JUMP A POSITIVE                        00580000 D
002B  02B0 0000 0000 00C0          OPR52-1=AMPCR          $LOAD B AND JUMP                        00590000 D
002C  02C0 0000 0000 C0C0          OPR53-1=AMPCR          $JUMP ON NO OVERFLOW                    005A0000 C
002D  02D0 0000 0000 00C0          OPR54-1=AMPCR          $LOAD CMR TASK                          005B0000 D
002E  02E0 0000 0000 00C0          OPR55-1=AMPCR          $LOAD CMR INCREMENT                     005C0000 D
002F  02F0 0000 0000 C0C0          OPR56-1=AMPCR          $STORE CMR TASK                         005D0000 D
0030  0300 0000 0000 00C0          OPR57-1=AMPCR          $STORE CMR INTERRUPT                    005E0000 D
0031  0310 0000 0000 00C0          OPR60-1=AMPCR          $STORE CMR IN A                         005F0000 D
0032  0320 0000 0000 C0C0          OPR61-1=AMPCR          $LOAD CMR FROM A                        00600000 C
0033  0330 0000 0000 00C0          OPR62-1=AMPCR          $SHIFT LEFT CIRCULARLY                  00610000 D
0034  0340 0000 0000 00C0          OPR63-1=AMPCR          $SHIFT LEFT CIRCULARLY DOUBLE           00620000 D
0035  0350 0000 0000 00C0          OPR64-1=AMPCR          $SHIFT RIGHT FILL ZEROS                 00630000 C
0036  0360 0000 0000 00C0          OPR65-1=AMPCR          $SHIFT RIGHT DOUBLE FILL ZEROS          00640000 D
0037  0370 0000 0000 00C0          OPR66-1=AMPCR          $SHIFT RIGHT FILL SIGN                  00650000 D
0038  0380 0000 0000 00C0          OPR67-1=AMPCR          $SHIFT RIGHT DOUBLE FILL SIGN           00660000 D
0039  0390 0000 0000 00C0          OPR70-1=AMPCR          $SCALE FACTOR                           00670000 D
003A  03A0 0000 0000 00C0          OPR71-1=AMPCR          $LOGICAL SUMM                           00680000 D
003B  03B0 0000 0000 0040          ILLEGAL4-1=MPCR        $PRINT MESSAGE & RETURN TO HALFFETCH    00690000 D
003C  03C0 0000 0000 0040          ILLEGAL4-1=MPCR        $PRINT MESSAGE & RETURN TO HALFFETCH    006A0000 D
003D  03D0 0000 0000 00C0          OPR74-1=AMPCR          $MULTIPLY REGISTER                      006B0000 D
003E  03E0 0000 0000 0040          ILLEGAL4-1=MPCR        $PRINT MESSAGE & RETURN TO HALFFETCH    006C0000 D
003F  03F0 0000 0000 0040          ILLEGAL4-1=MPCR        $PRINT MESSAGE & RETURN TO HALFFETCH    006D0000 D
0040  0400 0000 0000 C0C0          OPR77-1=AMPCR          $STORE IOC MONITOR CLOCK IN A           006E0000 D
                                OPR01XX:                                                         006F0000 D
0041  0410 0000 0000 00C0          OPR01X0-1=AMPCR                                               00700000 D
0042  0420 0000 0000 00C0          OPR01X1-1=AMPCR                                               00710000 D
0043  0430 0000 0000 C0C0          OPR01X2-1=AMPCR                                               00720000 D
0044  0440 0000 0000 00C0          OPR01X3-1=AMPCR                                               00730000 D
0045  0450 0000 0000 00C0          OPR01X4-1=AMPCR                                               00740000 D
0046  0460 0000 0000 00C0          OPR01X5-1=AMPCR                                               00750000 D
0047  0470 0000 0000 00C0          OPR01X6-1=AMPCR                                               00760000 D
0048  0480 0000 0000 00C0          OPR01X7-1=AMPCR                                               00770000 D
                                OPR02XX:                                                         00780000 D
0049  0490 0000 0000 00C0          OPR02X0-1=AMPCR                                               00790000 D
004A  04A0 0000 0000 00C0          ILLEGAL-1=AMPCR                                               007A0000 D
004B  04B0 0000 0000 C0C0          OPR02X2-1=AMPCR                                               007B0000 D
004C  04C0 0000 0000 C0C0          OPR02X3-1=AMPCR                                               007C0000 D
004D  04D0 0000 0000 C0C0          OPR02X4-1=AMPCR                                               007D0000 D
004E  04E0 0000 0000 00C0          OPR02X5-1=AMPCR                                               007E0000 D
004F  04F0 0000 0000 00C0          OPR02X6-1=AMPCR                                               007F0000 D
0050  0500 0000 0000 00C0          OPR02X7-1=AMPCR                                               00800000 D
                                OPR03XX:  $USES OPR01XX ROUTINES DUE TO DUPLICATION OF CODE      00810000 D
                                OPR05XX:                                                         00820000 D
0051  0510 0000 0000 C0C0          OPR05X0-1=AMPCR                                               00830000 D
0052  0520 0000 0000 00C0          OPR05X1-1=AMPCR                                               00840000 D
0053  0530 0000 0000 C0C0          OPR05X2-1=AMPCR                                               00850000 D
0054  0540 0000 0000 00C0          OPR05X3-1=AMPCR                                               00860000 D
0055  0550 0000 0000 C0C0          OPR05X4-1=AMPCR                                               00870000 D
0056  0560 0000 0000 00C0          ILLEGAL-1=AMPCR                                               00880000 D
0057  0570 0000 0000 00C0          ILLEGAL-1=AMPCR                                               00890000 D
0058  0580 0000 0000 00C0          ILLEGAL-1=AMPCR                                               008A0000 D
                                OPR06XX:                                                         008B0000 D
0059  0590 0000 0000 00C0          OPR06X0-1=AMPCR                                               008C0000 D
005A  05A0 0000 0000 C0C0          OPR06X1-1=AMPCR                                               008D0000 D
005B  05B0 0000 0000 00C0          OPR06X2-1=AMPCR                                               008E0000 D
005C  05C0 0000 0000 C0C0          OPR06X3-1=AMPCR                                               008F0000 C
005D  05D0 0000 0000 00C0          OPR06X4-1=AMPCR                                               00900000 D
005E  05E0 0000 0000 C0C0          OPR06X5-1=AMPCR                                               00910000 D
005F  05F0 0000 0000 00C0          OPR06X6-1=AMPCR                                               00920000 C
0060  0600 0000 0000 00C0          OPR06X7-1=AMPCR                                               00930000 D
```

```
                                OPR07XX:                                                                      01180000 D
0061  0610 0000 0000 00C0                  OPR07X0-1=AMPCR                                                    01190000 D
0062  0620 0000 0000 00C0                  OPR07X1-1=AMPCR                                                    01200000 D
0063  0630 0000 0000 00C0                  OPR07X2-1=AMPCR                                                    01210000 D
0064  0640 0000 0000 00C0                  OPR07X3-1=AMPCR                                                    01220000 D
0065  0650 0000 0000 00C0                  OPR07X4-1=AMPCR                                                    01230000 D
0066  0660 0000 0000 00C0                  OPR07X5-1=AMPCR                                                    01240000 D
0067  0670 0000 0000 00C0                  OPR07X6-1=AMPCR                                                    01250000 D
0068  0680 0000 0000 00C0                  ILLEGAL-1=AMPCR                                                    01260000 D
                                OPR50XX:                                                                      01270000 D
0069  0690 0000 0000 00C0                  OPR50X0-1=AMPCR                                                    01280000 D
006A  06A0 0000 0000 00C0                  OPR50X1-1=AMPCR                                                    01290000 D
006B  06B0 0000 0000 00C0                  OPR50X2-1=AMPCR                                                    01300000 D
006C  06C0 0000 0000 00C0                  OPR50X3-1=AMPCR                                                    01310000 D
006D  06D0 0000 0000 00C0                  ILLEGAL-1=AMPCR                                                    01320000 D
006E  06E0 0000 0000 00C0                  ILLEGAL-1=AMPCR                                                    01330000 D
006F  06F0 0000 0000 00C0                  ILLEGAL-1=AMPCR                                                    01340000 D
0070  0700 0000 0000 00C0                  ILLEGAL-1=AMPCR                                                    01350000 D
                                OPR51XX:                                                                      01360000 D
0071  0710 0000 0000 00C0                  OPR51X0-1=AMPCR                                                    01370000 D
0072  0720 0000 0000 00C0                  OPR51X1-1=AMPCR                                                    01380000 D
0073  0730 0000 0000 00C0                  OPR51X2-1=AMPCR                                                    01390000 D
0074  0740 0000 0000 00C0                  OPR51X3-1=AMPCR                                                    01400000 D
0075  0750 0000 0000 00C0                  ILLEGAL-1=AMPCR                                                    01410000 D
0076  0760 0000 0000 00C0                  ILLEGAL-1=AMPCR                                                    01420000 D
0077  0770 0000 0000 00C0                  ILLEGAL-1=AMPCR                                                    01430000 D
0078  0780 0000 0000 00C0                  ILLEGAL-1=AMPCR                                                    01440000 D
                                OPR52XX:                                                                      01450000 D
0079  0790 0000 0000 00C0                  OPR52X0-1=AMPCR                                                    01460000 D
007A  07A0 0000 0000 00C0                  OPR52X1-1=AMPCR                                                    01470000 D
007B  07B0 0000 0000 00C0                  OPR52X2-1=AMPCR                                                    01480000 D
007C  07C0 0000 0000 00C0                  OPR52X3-1=AMPCR                                                    01490000 D
007D  07D0 0000 0000 00C0                  ILLEGAL-1=AMPCR                                                    01500000 D
007E  07E0 0000 0000 00C0                  ILLEGAL-1=AMPCR                                                    01510000 D
007F  07F0 0000 0000 00C0                  ILLEGAL-1=AMPCR                                                    01520000 D
0080  0800 0000 0000 00C0                  ILLEGAL-1=AMPCR                                                    01530000 D
                                OPR53XX:                                                                      01540000 D
0081  0810 0000 0000 00C0                  OPR53X0-1=AMPCR                                                    01550000 D
0082  0820 0000 0000 00C0                  OPR53X1-1=AMPCR                                                    01560000 D
0083  0830 0000 0000 00C0                  OPR53X2-1=AMPCR                                                    01570000 D
0084  0840 0000 0000 00C0                  OPR53X3-1=AMPCR                                                    01580000 D
0085  0850 0000 0000 00C0                  ILLEGAL-1=AMPCR                                                    01590000 D
0086  0860 0000 0000 00C0                  ILLEGAL-1=AMPCR                                                    01600000 D
0087  0870 0000 0000 00C0                  ILLEGAL-1=AMPCR                                                    01610000 D
                                OPR70XX:                                                                      01620000 D
0088  0880 0000 0000 00C0                  OPR70X0-1=AMPCR                                                    01630000 D
0089  0890 0000 0000 00C0                  OPR70X1-1=AMPCR                                                    01640000 D
008A  08A0 0000 0000 00C0                  OPR70X2-1=AMPCR                                                    01650000 D
008B  08B0 0000 0000 00C0                  OPR70X3-1=AMPCR                                                    01660000 D
008C  08C0 0000 0000 0040                  ILLEGAL4-1=MPCR     $PRINT MESSAGE & RETURN TO HALFFETCH 01670000 D
008D  08D0 0000 0000 0040                  ILLEGAL4-1=MPCR     $PRINT MESSAGE & RETURN TO HALFFETCH 01680000 D
008E  08E0 0000 0000 0040                  ILLEGAL4-1=MPCR     $PRINT MESSAGE & RETURN TO HALFFETCH 01690000 D
008F  08F0 0000 0000 0040                  ILLEGAL4-1=MPCR     $PRINT MESSAGE & RETURN TO HALFFETCH 01700000 D
                                OPR74XX:                                                                      01710000 D
0090  0900 0000 0000 00C0                  OPR74X0-1=AMPCR                                                    01720000 D
0091  0910 0000 0000 00C0                  OPR74X1-1=AMPCR                                                    01730000 D
0092  0920 0000 0000 00C0                  OPR74X2-1=AMPCR                                                    01740000 D
0093  0930 0000 0000 00C0                  OPR74X3-1=AMPCR                                                    01750000 D
0094  0940 0000 0000 00C0                  OPR74X4-1=AMPCR                                                    01760000 D
0095  0950 0000 0000 00C0                  OPR74X5-1=AMPCR                                                    01770000 D
```

```
0096  096C 0000 0030 00C0          OPR74X6-1=AMPCR                                                 01780000 D
0097  0970 0000 0030 00CC          OPR74X7-1=AMPCR                                                 01790000 D
                                OPR77XX:                                                          01800000 D
0098  0980 00C0 0030 00C0          OPR77X0-1=AMPCR                                                 01810000 D
0099  0990 0000 0030 00C0          OPR77X1-1=AMPCR                                                 01820000 D
009A  09A0 0000 0000 0040          ILLEGAL4-1=MPCR          %PRINT MESSAGE & RETURN TO HALFFETCH   01830000 D
009B  09B0 0000 0000 0040          ILLEGAL4-1=MPCR          %PRINT MESSAGE & RETURN TO HALFFETCH   01840000 D
009C  09C0 0000 0030 00C0          OPR77X4-1=AMPCR                                                 01850000 D
009D  09D0 0000 0030 00C0          OPR77X5-1=AMPCR                                                 01860000 D
009E  09E0 0000 0030 00C0          OPR77X6-1=AMPCR                                                 01870000 D
009F  09F0 00C0 0030 0040          ILLEGAL4-1=MPCR          %PRINT MESSAGE & RETURN TO HALFFETCH   01880000 D
                                %                                                                 01890000 D
                                %  START BY TRYING TO SET GC1 WHICH MEANS THE                     01900000 D
                                %  LOADER HAS LOADED THE OBJECT CODE AND                          01910000 D
                                %  PRESET THE REGISTERS                                           01920000 D
                                %  IN GENERAL A2 CONTAINS ASR/PAR, A1 CONTAINS CURRENT INSTRUCTION 01930000 D
00A0  580C 0000 0020 C0F0     START:  0 = BR1; WAIT                                               01940000 D
00A1  0988 00C0 0000 00FC             SET GC1; WHEN GC1 THEN STEP                                 01950000 D
00A2  0A0C 00C0 0030 0060             GETPAR-1 = CPCR                                             01960000 D
00A3  48C9 00C1 0B30 00F0             1 L=B;RESET GC2          %ADD 1024 TO STARTING ADDRESS      01970000 D
00A4  A00C 0000 0000 0020             COMP 10=SAR                                                 01980000 D
00A5  4809 CC40 2030 00F0             A2+B=A2                  %A2 = STARTING ADDRESS OFFSET 1024 01990000 D
                                IFETCH:                                                           02000000 D
00A6  0A10 0000 0000 0060             PUTPAR-1 = CPCR                                             02010000 D
00A7  3808 0000 0C30 00F0             IF IRQ THEN STEP ELSE SKIP                                  02020000 D
00A8  0A20 0000 0000 0060             IODUMPREG-1 = CPCR                                          02030000 D
00A9  1808 0000 0000 00F0             IF GC2 THEN STEP ELSE SKIP                                  02040000 D
00AA  0A30 0000 0000 0060             GC2CHECK-1 = CPCR                                           02050000 D
                                IFETCH1:                                                          02060000 D
00AB  4809 C0C0 001C 00FC             A2 = MAR2                                                   02070000 D
00AC  A809 0000 0000 0CF0             MR2; IF RDC              % READ NEXT INST.                  02080000 D
00AD  AC08 C0C0 2C00 00F0             WHEN RDC THEN A2 + 1 = A2,BEX   % INC PAR                   02090000 D
                                IFETCHREMOTE:   %ENTRY FROM EXECUTE REMOTE OPRO2X2                02100000 D
00AE  4809 0C40 4000 00F0             B = A1                   % A1 => CURRENT INST.              02110000 D
00AF  4809 0C40 8B00 00F0             B R = B                                                     02120000 D
00B0  0000 00C0 0000 0020             16 = SAR                                                    02130000 D
00B1  4809 0C40 0030 00F0             B                                                           02140000 D
00B2  580B 0000 0C30 00F0             IF LST THEN STEP ELSE SKIP                                  02150000 D
00B3  0A40 0000 0C30 C060             INDIRECT-1 = CPCR        % INDIRECTION                      02160000 D
                                IFETCH2:                                                          02170000 D
00B4  4809 A0C0 8B00 00F0             A1 R = B                                                    02180000 D
00B5  1070 0003 0000 00A0             7 = LIT; 17 = SAR                                           02190000 D
00B6  4809 2C56 0B30 00FC             LIT AND B = B            % B-FIELD                          02200000 D
00B7  4809 A0C0 8040 00F0             A1 R = AMPCR             % OPCODE                           02210000 D
00B8  2080 0000 0C00 00B0             BBASE = LIT; 26 = SAR                                       02220000 D
00B9  4809 0000 0030 00F0             STEP                                                        02230000 D
00BA  2824 2C40 100C 00F0             LIT + B = MAR,A3; EXEC; IF LC1    % B(B) ADDR =>MAR,A3     02240000 D
00BB  382D 0000 0000 00F0             JUMP; IF LC2             % JUMP TO OPCODE                   02250000 D
                                %                                                                 02260000 D
                                %                                                                 02270000 D
                                % ************************    SUBR FOR MEMORY FETCHES    ********** 02280000 D
                                HALFFETCH:     %FETCH THE NEXT HALFWORD INSTRUCTION               02290000 D
00BC  9809 0000 0030 18F0             MW1; IF SAI              %WRITE RESULTS OF PREVIOUS HALFWORD 02300000 D
                                      %SOME INSTRUCTIONS ENTER HERE AT HALFFETCH+1                 02310000 D
00BD  4809 A0C1 C0B0 00F0             A1 C=A1                  %FETCH LOWER HALFWORD              02320000 D
00BE  0000 0000 0000 0020             16=SAR                   %SWITCH UPPER AND LOWER WORDS      02330000 D
00BF  4809 A0C0 9000 00F0             A1 R=A3                  %ISOLATE & SAVE OPCODE             02340000 D
00C0  2000 00C0 0030 0030             26=SAR                                                      02350000 D
00C1  4809 C001 8B30 40F0             A2 C=B,CSAR                                                 02360000 D
00C2  8000 0000 0000 0020             20=SAR                   %GET HALFWORD FLAG TO LSB          02370000 D
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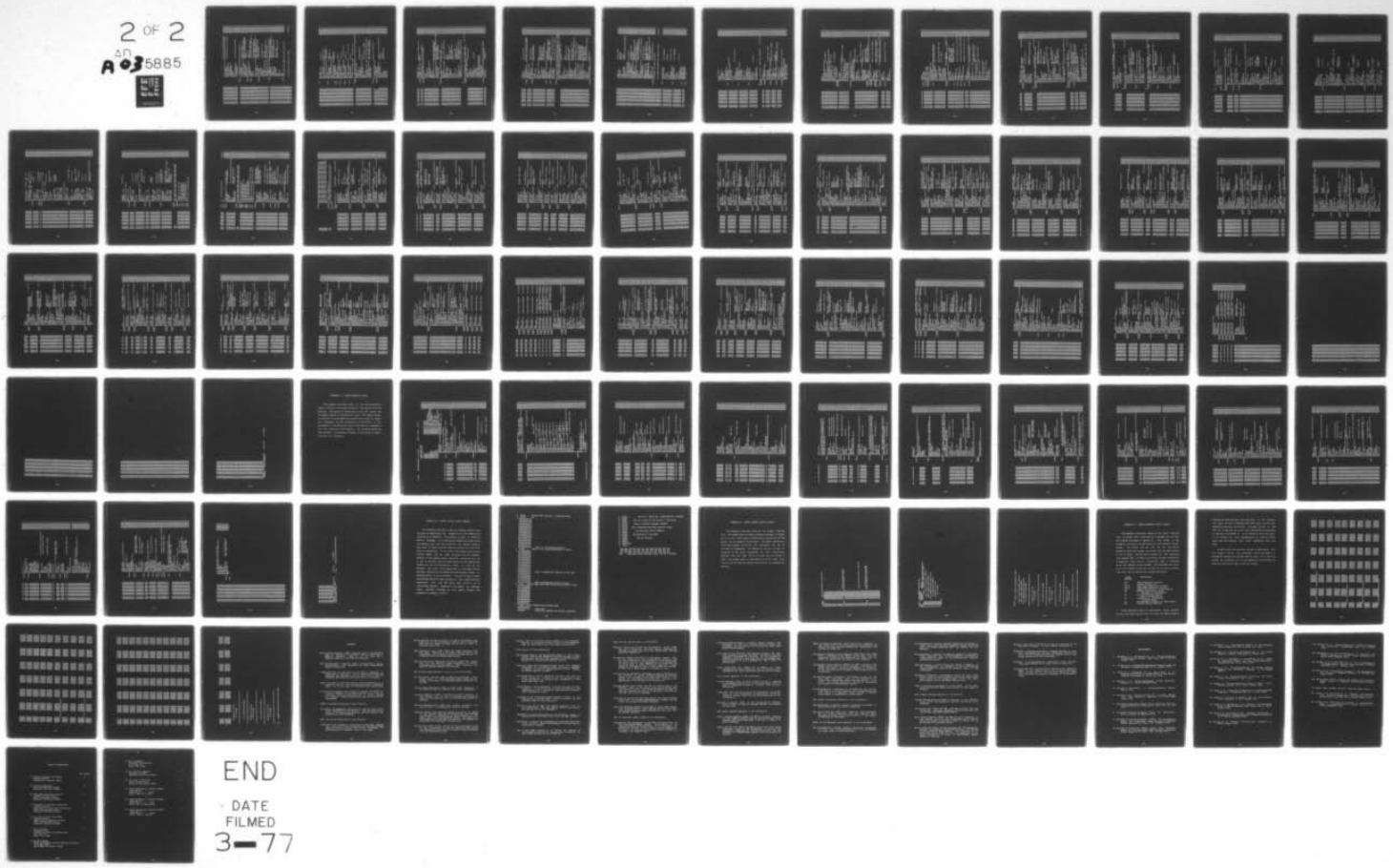
AD-A035 885 NAVAL POSTGRADUATE SCHOOL MONTEREY CALIF F/G 9/2
EMULATION OF THE AN/UYK-7 TACTICAL DATA COMPUTER ON THE BURROUG--ETC(U)
DEC 76 J M HAGGERTY, J M HARTLING

UNCLASSIFIED NL

2 OF 2
AD
A035885



END

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3-77

```
00C3  9809 0C40 009C 00F0          B                          %TEST BIT SET=>PREVIOUS HALFWORD      02380000 D
00C4  5C00 0C01 A090 00F0          IF LST THEN BTTO C=A2; STEP ELSE SKIP  %SET BIT IF CLEARED       02390000 D
00C5  0A50 0000 0000 C040          IFETCH-1=MPCR                                                    02400000 D
00C6  3809 0CC1 A090 00F0          BTT1 C=A2;IF LC2           %CLEAR REPEAT BIT IF SET;GET NEXT     02410000 D
00C7  8019 0000 0000 00F0          IF NOT IRQ THEN SKIP                                             02420000 D
00C8  0A5C 0003 0030 0060          PUTPAR-1=CPCR                                                    02430000 D
00C9  8019 0000 0030 00F0          IF NOT IRQ THEN SKIP                                             02440000 D
00CA  0A60 0003 0030 0060          IODUMPREG-1=CPCR                                                 02450000 D
00CB  9809 E000 0C40 00F0          A3=AMPCR                                                         02460000 D
00CC  9809 0000 0030 00F0          STEP                                                             02470000 D
00CD  2024 E012 0000 00F0          A3 EQL 0;EXEC;IF LC1       %IF LOWER OPC=0 DON:T EXECUTE         02480000 D
00CE  6029 0000 0030 00F0          IF FALSE THEN JUMP                                               02490000 D
00CF  00C0 0000 0C30 0040          HALFFETCH=MPCR                                                   02500000 D
                                   %                                                                02510000 D
                                   YFETCH:    %MAR=B(B) ADDRESS%;RETURN MAR2=Y-ADDR;MIR=Y(K)        02520000 D
00D0  A809 A000 9000 00F0          A1 R=A3;IF RDC                                                   02530000 D
00D1  B07C 0003 0030 00A0          7=LIT;20=SAR               %ISOLATE K FIELD                      02540000 D
00D2  A809 E156 1035 00F0          A3 AND LIT=CTR,A3;MR1;IF RDC %SAVE K IN CTR;READ P(B)            02550000 D
00D3  1019 0000 0030 00F0          IF NOT GC2 THEN SKIP       %GC2 SET IF SPECIAL CONDITIONS        02560000 D
00D4  0A70 00C0 0C00 0040          YABNORMAL-1=MPCR           %CHECK FOR SPECIAL CONDITIONS         02570000 D
00D5  AC08 00C0 0C00 00F0          WHEN RDC THEN BEX          %B=B(B)                               02580000 D
00D6  9809 E002 0000 C0F0          YREPFETCH:  NOT A3                                               02590000 D
00D7  6C19 0C40 0030 00F0          IF ABT THEN B=MIR;SKIP     %CHECK K=0                            02600000 D
00D8  0A8C 0000 0C30 C040          KNOTZERO-1=MPCR            %%JUMP HERE IF KNOT = ZERO            02610000 D
00D9  9809 0018 0B90 00F0          KZERO:  B111 R=B           %ARRIVE HERE FROM ABNORMAL NOT CA     02620000 D
00DA  0000 0000 0000 0020          16=SAR                                                           02630000 D
00DB  9809 A0C1 1090 00F0          A1 L=A3                    %CHECK SIGN OF SY-FIELD               02640000 D
00DC  9809 E0C0 0000 00F0          A3                         %A3= SY SHIFTED LEFT TO MSB           02650000 D
00DD  9C19 EC53 9D80 00F0          IF MST THEN A3 OR B C=A3,BMI;SKIP  %EXTEND NEGATIVE SIGN         02660000 D
00DE  9809 E000 9D80 00F0          A3 R = A3,BMI              %EXTEND POSITIVE SIGN                 02670000 D
00DF  982D EC40 1030 00F0          A3+B=A3,MIR;JUMP           %Y=SY(SE)+B(B);GO TO OPCODE           02680000 D
00E0  9809 A0C3 9000 00F0          KNOTZERO:  A1 R=A3         %ISOLATE S-FIELD                      02690000 D
00E1  9070 0003 0000 0090          7=LIT;13=SAR                                                     02700000 D
00E2  9809 E156 103C C0F0          A3 AND LIT=A3                                                    02710000 D
00E3  9809 E140 0C3C 00F0          A3+LIT=MAR                 %MAR=ADDRESS OF S(S)                  02720000 D
00E4  0100 00C0 0030 C0E0          SBASE=LIT                                                        02730000 D
00E5  A809 A0C1 1030 40F0          A1 L=A3,C%AR;MR1;IF RDC    %READ S(S)                            02740000 D
00E6  9809 E0C0 9000 00F0          A3.R=A3                    %A3=Y-FIELD ISOLATED RIGHT            02750000 D
00E7  AC08 EC40 1C00 C0F0          WHEN RDC THEN A3+B=A3,BEX  %B=S(S); A3=Y+B(B)                    02760000 D
00E8  9809 EC4C 001C 00F0          A3+B=MAR2                                                        02770000 D
                                   YFETCH1:   %RETURN HERE FROM Y-ABNORMAL UNLESS K=0 OR CHAR ADDR.  02780000 D
00E9  9809 0640 009C 24F0          AMPCR=MIR;ASE              %SELECT BR2=K; SAVE RETURN            02790000 D
00EA  9809 0B02 9000 00F0          NOT CTR R=A3               %RESTORE K IN MSB INPUT FROM CTR      02800000 D
00EB  000C 0003 0030 0030          24=SAR                     %SHIFT CTR TO LSB                     02810000 D
00EC  9809 E640 009C 00F0          A3+AMPCR=AMPCR             %SET UP K-HANDLER ROUTINES            02820000 D
00ED  0A90 00C0 0030 00CC          KTABLE-1=AMPCR                                                   02830000 D
00EE  A809 0003 0030 CCF0          MR2;IF RDC                 %READ Y VALUE                         02840000 D
00EF  9824 0003 0030 00F0          EXEC                       %EXECUTE K-HANDLER ROUTINE            02850000 D
00F0  9836 00C3 0000 C0F0          CALL                                                             02860000 D
00F1  9809 0C40 0040 C0FC          B = AMPCR                                                        02870000 D
00F2  9809 0003 0030 00FC          STEP                                                             02880000 D
00F3  982D 0003 003C C0F0          JUMP                                                             02890000 D
00F4  980C 0003 0000 00F0          KTABLE: WAIT                                                     02900000 D
00F5  0AAC 0003 00C0 00C0          KR1-1=AMPCR. KR2-1=AMPCR. KR3-1=AMPCR. KR4-1=AMPCR               02910000 D
00F6  0AB0 00C3 0030 00C0
00F7  0AC0 00C3 0030 00C0
00F8  0AD0 0003 0000 00C0
00F9  0AE0 00C3 0030 00C0          KR5-1=AMPCR. KR6-1=AMPCR. KR7-1=AMPCR                            02920000 D
00FA  0AF0 0003 0030 C0C0
00FB  00DC 0003 0030 00C0
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0CFC  0000 0000 0090 0020    KR1:   16 = SAR                                                  02930C00 D
0CFD  AC08 00C0 0C90 C0FC           WHEN RDC THEN BEX          % READ (Y)                    02940C00 D
0CFE  9809 0C41 1090 C0F0           B L = A3                                                 02950000 D
0CFF  9809 E0C0 9090 C0F0           A3 R = A3,MIR,BMI          % (Y) 0-15 = MIR              02960C00 D
0100  9C0D 0C40 0090 00F0           IF MST THEN B=MIR; STEP ELSE JUMP                        02970C00 D
0101  9809 0019 0B90 00F0           B111 L = B                 % 1:S IN BITS 16-31            02980C00 D
0102  9820 EC5C 1090 00F0           A3 OR B = A3,MIR,BMI;JUMP  % SIGN EXTENDED               02990C00 D
0103  000C 0000 0080 0020    KR2:   16 = SAR                                                  03000C00 D
0104  AC08 0000 0C90 C0F0           WHEN RDC THEN BEX          % READ (Y)                    03010C00 D
0105  9809 0C40 9090 00F0           B R = A3,MIR,BMI           % (Y) 31-16 = A3              03020C00 D
0106  9C0D 0C40 0090 00F0           IF MST THEN B=MIR;STEP ELSE JUMP                         03030C00 D
0107  9809 0019 0B00 00F0           B111 L = B                                               03040C00 D
0108  982D EC5C 1090 00F0           A3 OR B = A3,MIR,BMI; JUMP %EXTEND SIGN                  03050000 D
0109  AC08 00C0 0C90 00F0    KR3:   WHEN RDC THEN BEX          % READ (Y)                    03060000 D
010A  982D 0C40 1090 00F0           B = A3,MIR,BMI;JUMP                                      03070C00 D
010B  0FFC 0000 0090 C0E0    KR4:   255 = LIT                                                 03080C00 D
010C  AC08 0000 0C90 00F0           WHEN RDC THEN BEX          % READ (Y)                    03090C00 D
010D  9820 2C56 109C 00F0           LIT AND B = A3,MIR,BMI;JUMP                              03100C00 D
010E  0FF0 0000 009C 0090    KR5:   255 = LIT; 0 = SAR                                       03110C00 D
010F  AC08 00C0 0C90 00F0           WHEN RDC THEN BEX          % READ (Y)                    03120C00 D
0110  9809 0C40 0B90 00F0           B R = B                                                  03130C00 D
0111  9820 2C56 1090 C0F0           LIT AND B = A3,MIR,BMI;JUMP     % (Y) 15-8 = MIR         03140C00 D
0112  0FF0 0000 0090 00A0    KR6:   255 = LIT; 16 = SAR                                      03150C00 D
0113  AC08 0000 0C90 C0F0           WHEN RDC THEN BEX          % READ ( Y)                   03160C00 D
0114  9809 0C40 0B90 00F0           B R = B                                                  03170C00 D
0115  9820 2C56 1090 00F0           LIT AND B = A3,MIR,BMI; JUMP     % (Y) 23-16 = MIR       03180C00 D
0116  0FF0 0000 0090 0080    KR7:   255 = LIT; 24 = SAR                                      03190C00 D
0117  AC08 0000 0C90 00F0           WHEN RDC THEN BEX          %READ (Y)                     03200C00 D
0118  9809 0C40 0B90 00F0           B R = B                                                  03210C00 D
0119  9820 2C56 1090 00F0           LIT AND B = A3,MIR,BMI; JUMP     % (Y) 31-24 = MIR       03220C00 D
                                   %                                                        03230C00 D
                                   YABNORMAL: %CALLED FROM Y-FETCH WHEN GC2 SET MAR=B-FIELD;A3,BR2=K-FIELD 03240C00 D
011A  AC08 E0C0 0095 C0F0           WHEN RDC THEN A3=B,CTR                                   03250C00 D
011B  9809 C0C0 9000 00F0           A2 R=A3                                                  03260000 D
011C  9070 0000 0090 00A0           21=SAR;7=LIT                                             03270C00 D
011D  9809 E155 9C90 00F0           A3 AND LIT R=A3            %A3=SPEC.COND.BITS            03280C00 D
011E  11BC 0000 0090 0080           1=SAR;YADDR=LIT                                          03290C00 D
011F  5C0B 0C40 1C90 C0F0           IF LST THEN B=A3,BEX;STEP ELSE SKIP                      03300C00 D
0120  005C 00C0 0090 0040           YREPFETCH-1=MPCR                                         03310C00 D
0121  9809 0000 0030 C0F0           LMAR                       %READ PRECALC. Y-ADDRESS      03320C00 D
0122  A809 0000 0000 00F0           MR1;IF RDC                                               03330C00 D
0123  AC08 E152 0C00 00F0           WHEN RDC THEN A3 EQL LIT,BEX  %TEST=3=>CHAR.ADDR;E=Y-ADDR 03340C00 D
0124  0030 0000 0070 0080           3=LIT;24=SAR                                             03350C00 D
0125  6419 0C43 001C 00F0           IF FALSE THEN B=MAR2;SKIP  %NOT CA S0 SETUP Y-ADDRESS    03360C00 D
0126  0B1C 00C3 0090 0040           CHARFETCH-1=MPCR           %MUST HAVE BEEN 3=>CHAR.ADDR. 03370C00 D
0127  0E80 00C0 0090 0040           YFETCH1-1=MPCR                                           03380C00 D
                                   %                                                        03390C00 D
                                   Y2FETCH:                   %ISOLATE (Y) AND LEAVE IN B   03400C00 D
0128  180B 0000 0090 C0F0           IF GC2 THEN STEP ELSE SKIP                               03410C00 D
0129  0B2C 0000 0090 00          Y2ABNORMAL-1=MPCR                                          03420C00 D
012A  9809 A0C1 1000 40    Y2REPABN:  A1 L=A3,CSAR                                          03430C00 D
0128  9070 0000 0090 00           COMP 19=SAR;7=LIT                                        03440C00 D
012C  A809 E000 9B00 40F0          A3 R=A3,CSAR;MR1;IF RDC    %ISOLATED THE Y-FIELD;READ B(B) 03450C00 D
012D  AC08 0000 0C90 00F0          WHEN RDC THEN BEX          %B=B(B)                       03460C00 D
012E  9809 EC40 1090 C0F0          A3+B=A3                                                  03470C00 D
012F  9809 A0C0 0B00 00F0          A1 R=B                     %Y+B(B)=A3                    03480C00 D
0130  9809 2C56 0B00 00F0          LIT AND B=B                %ISOLATE S-FIELD              03490C00 D
0131  9809 2C40 0C0C 00F0          LIT+B=MAR                                                03500C00 D
0132  010C 0000 0C90 00E0          SBASE=LIT                                                03510C00 D
0133  A809 0000 0000 00F0          MR1;IF RDC                                               03520C00 D
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0134  AC08 0008 0C00 00F0          WHEN RDC THEN BEX                                                  03530C00 D
0135  4809 EC40 001C 00F0          A3+B=MAR2                  %B=Y-ADDR IF SPECIAL NOT CA             03540C00 D
                                Y2FETCH1:  %NORMAL RETURN FROM ~2ABNORMAL                            03550C00 D
0136  A809 0008 0000 0CF0          MR2;IF RDC                                                         03560C00 D
0137  AC20 0008 0C30 00F0          WHEN RDC THEN BEX;JUMP     %(Y) NOW IN B REGISTER                  03570C00 D
                                Y2ABNORMAL:  %CALLED FROM Y2 WHEN GC2 SET; MAR=B-REG                 03580000 D
0138  4809 C008 9030 00F0          A2 R=A3                                                            03590C00 D
0139  9000 0008 0000 0020          21=SAR                                                             03600C00 D
013A  4809 E156 9030 00F0          A3 AND LIT R=A3                                                    03610000 D
013B  1070 0008 0C30 0000          7=LIT;1=SAR                                                        03620000 D
013C  5419 0003 0000 00F0          IF NOT LST THEN LMAR;SKIP                                          03630000 D
013D  1290 0008 0090 0040          Y2REPABN-1=MPCR                                                    03640C00 D
013E  0180 0008 0090 00E0          YADDR=LIT                                                          03650C00 D
013F  A809 0008 0030 00F0          MR1;IF RDC                                                         03660C00 D
0140  AC08 E152 0C0C 00F0          WHEN RDC THEN A3 EQL LIT,BEX %TEST FOR CAR.ADDR.;E=B(B)             03670C00 D
0141  0030 0008 0000 00E0          3=LIT                      %CHECK FOR CHARACTER ADDR.              03680C00 D
0142  6408 0C40 001C 00F0          IF FALSE THEN B=MAR2;STEP ELSE SKIP %IF NOT CA THEN SETUP Y-ADDR 03690C00 D
0143  1350 0008 0090 0040          Y2FETCH1-1=MPCR            %NOT AMAR ADDRESSING                    03700C00 D
0144  0B30 0008 0C30 0040          CHARFETCH-1=MPCR           %CHARACTER ADDRESSING                   03710C00 D
                                %                                                                    03720C00 D
                                CHARFETCH:   %FETCH CHARACTER ADDRESSED BY Y=(B)                     03730C00 D
0145  4809 0C40 003C 00F0          B=MAR2,MIR                 %READ (Y);SAVE Y IN MIR                 03740C00 D
0146  A809 0008 0C30 0CF0          MR2;IF RDC                                                         03750C00 D
0147  AC08 2008 0C3C C0F0          WHEN RDC THEN LIT=MAR,BEX  %B=(Y);MAR=ICW ADDRESS TEMP.            03760C00 D
0148  01AC 0003 0030 00E0          IAW=LIT                                                            03770C00 D
0149  A809 0C40 1000 00F0          B=A3;MR1;IF RDC            %A3=(Y)                                 03780C00 D
014A  AC08 00C8 0C30 C0F0          WHEN RDC THEN BEX          %B=ICW                                  03790C00 D
014B  4809 0C40 8B00 C0F0          B R=B                      %B=-W/P                                 03800C00 D
014C  825C 0008 0000 00A0          20=SAR;37=LIT              %MASK FOR W&P FIELDS                    03810C00 D
014D  4809 2C56 0000 00F0          LIT AND B=SAR              %SAVE P-FIELD                           03820C00 D
014E  4809 E0C8 9C30 00F0          A3 R=A3                    %RIGHT JUSTIFY CHAR BY P                03830C00 D
014F  4809 0C40 8B00 00F0          B R=B                      %B=0C/W IN LSB                          03840C00 D
0150  9000 0008 0C30 0000          5=SAR                                                              03850C00 D
0151  4809 2C56 0000 00F0          LIT AND B=SAR              %W VALUE => SAR                         03860C00 D
0152  4809 00C0 0030 40F0          CSAR                       %COMPLEMENT SAR = NOT W                 03870C00 D
0153  4809 0018 0B00 00F0          B111 R=B                   %MASK FOR W BITS                        03880C00 D
0154  4809 EC56 1D90 00F0          A3 AND B=A3,MIR,BMI        %A3=DATA MASKED;B=Y ADDRESS             03890C00 D
0155  402D 0C40 001C 00F0          B=MAR2;JUMP                %B=Y ADDRESS                            03900000 D
                                %RETURN TO CALLING OP YFETCH OR Y2FETCH;MIR=CHAR IN LSB              03910C00 D
                                %                                                                    03920C00 D
                                %                                                                    03930C00 D
                                % ######################    SUBR. FOR MEMORY STORES    ############## 03940C00 D
                                YSTORE:    %CALLED FROM OPCODES VALUE TO STORE IS IN MIR             03950C00 D
                                %MAR1 IS SETUP TO READ B(B)                                          03960000 D
0156  4809 A008 9000 00F0          A1 R=A3                    %ISOLATE B-FIELD                        03970C00 D
0157  1070 0008 0030 00A0          17=SAR;7=LIT                                                       03980C00 D
0158  4809 E156 1090 00F0          A3 AND LIT=A3                                                      03990C0C D
0159  4809 E140 003C 00F0          A3+LIT=MAR                                                         04000C0C D
015A  000C 0008 0030 00E0          BBASE=LIT                                                          04010C00 D
015B  A809 A008 0B00 00F0          A1 R=B;MR1;IF RDC          %READ B(B)                              04020C0C D
015C  8070 0009 0090 00A0          7=LIT;20=SAR                                                       04030C00 D
015D  4809 2C56 1090 00F0          LIT AND B=A3                                                       04040C00 D
015E  0B40 0008 000C 00C0          KSTABLE-1=AMPCR                                                    04050C00 D
015F  AC08 E640 0C40 00F0          WHEN RDC THEN A3+AMPCR=AMPCR,BEX                                   04060C00 D
0160  1419 A001 1000 40F0          IF NOT GC2 THEN A1 L=A3,CSAR;SKIP                                  04070C00 D
0161  0B50 0008 0000 C040          YSABNORMAL-1=MPCR                                                  04080000 D
0162  9070 0009 0090 0090          COMP 19=SAR;7=LIT                                                  04090C00 D
                                YSTORE2:   %RETURN HERE FROM ABNORMAL IF NOT REPLACE ABNORMAL        04100C00 D
0163  4809 E9C8 9090 00F0          A3 R=A3                    %ISOLATE Y-FIELD                        04110C00 D
0164  4809 EC40 1090 40F0          A3+B=A3,CSAR               %Y+B(B)=A3                              04120C00 D
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0165  4809 A0C0 8B30 00F0          A1 R=B                                                    04130C00 D
0166  4809 2C56 0B90 00F0          LIT AND B=B                 $ISOLATES S-FIELD             04140C00 D
0167  4809 2C40 0C3C C0F0          LIT+B=MAR                                                 04150C00 D
0168  0100 0000 0C00 C0A0          16=SAR; SBASE=LIT           $SAR SETUP FOR USE BY KS ROUTINES 04160C00 D
                                YSTORE1:  $RETURN FERE FROM ALL INDIR EXCEPT CA AND REPLACE REPEAT 04170C00 D
0169  A809 0003 0030 00FC          MR1;IF RDC                                                04180C00 D
016A  AC20 0000 0C00 00FC          WHEN RDC THEN BEX;EXEC                                    04190C00 D
016B  4809 EC43 0C1C C0F0          A3+B=MAR2                   $MAR2=Y+B(B)+S($)             04200000 D
016C  A82D 0000 0C0C 0CF0          JUMP;MR2;IF RDC                                           04210C00 D
                                YSABNORMAL:  $CALLED FROM YSTORE; AMPCR=K-HANDLER;B=B(B)   04220C00 D
016D  4809 C000 9C00 00F0          A2 R=A3                     $ISOLATE SPEC COND BITS       04230C00 D
016E  9070 0000 0000 00A0          21=SAR; 7=LIT                                             04240C00 D
016F  4809 E156 9000 00F0          A3 AND LIT R=A3                                           04250C00 D
0170  1000 0000 0030 0000          1=SAR                                                     04260C00 D
0171  5419 E152 0000 00F0          IF NOT LST THEN A3 EQL LIT;SKIP                           04270C00 D
0172  0860 0000 0000 0040          YSREP-1=MPCR                $MUST BE REPEAT STORE         04280000 D
0173  0030 0000 0000 00E0          3=LIT                       $CODE FOR CHAR ADDR.          04290C00 D
0174  6819 00C0 0030 00F0          IF TRUE THEN SKIP           $TEST FOR CA                  04300000 D
0175  0870 0000 0000 0040          YSABN-1=MPCR                $NOT CHAR ADDRESSING          04310C00 D
0176  0080 0000 0000 0060          CHARSTORE-1=CPCR            $CA STORE CHAR AND RETURN     04320C00 D
0177  0A50 0000 0C30 0040          IFETCH-1=MPCR                                             04330C00 D
                                YSABN:  $REPEAT/OPT. INDIR./INDIR. NOT CHAR ADDR.         04340C00 D
0178  4809 0000 1008 00F0          0=A3,LMAR                   $READ PRECALCULATED ADDRESS OF Y 04350C00 D
0179  0180 0000 0000 C0E0          YADDR=LIT                   $ADDRESS OF PRECALC. Y-ADDR.  04360C00 D
017A  1680 0000 0030 0040          YSTORE1-1=MPCR              $LET YSTORE READ/WRITE USING K 04370C00 D
017B  3419 A0C1 1000 40F0      YSREP:  IF NOT LC2 THEN A1 L=A3,CSAR;SKIP                     04380C00 D
017C  1770 0000 0000 C040          YSABN-1=MPCR                $REPLACE THEN USE PRECALC ADDR OF Y 04390C00 D
017D  9070 00C0 0000 0090          COMP 19=SAR;7=LIT                                         04400C00 D
017E  1620 0000 0000 C040          YSTORE2-1=MPCR              $NOT REPLACE REPEAT CALC ADDRESS 04410C00 D
                                $                                                         04420C00 D
                                CHARSTORE:  $CALLED FROM YSTORE IF CHAR ADDR.;MASK WORD IN MIR BY W BITS04430C00 D
                                $SHIFT BACK TO P POSIT. AND OUTPUT TO Y. IF SINGLE CA TO Y ADDR.04440C00 D
                                $IN (19) ELSE TO Y OR Y+1 AT (19) DEPENDING ON LC1=P-W LT 0 = P 04450C00 D
                                $OR P-W GE 0 = P;UPDATE P AND STORE AT ADDRESS (2C).       04460C00 D
017F  4809 0000 0008 C0F0          LMAR                        $READ ICW                     04470000 D
0180  01A0 0000 0000 C0E0          IAW=LIT                                                   04480C00 D
0181  A809 0000 0030 00F0          MR1;IF RDC                                                04490C00 D
0182  AC08 0000 0C00 00F0          WHEN RDC THEN BEX           $B=ICW                        04500000 D
0183  4809 0C40 9030 00F0          B R=A3                      $ISOLATE BITS 31 & 30         04510C00 D
0184  A030 0000 0000 00B0          30=SAR; 3=LIT                                             04520C00 D
0185  4809 E152 0000 00F0          A3 EQL LIT                  $SEQUENTIAL CA CHECK          04530C00 D
0186  6419 0C40 9000 00F0          IF FALSE THEN B R=A3; SKIP $B=ICW;A3=0C/W/P               04540C00 D
0187  0B90 0000 0C00 0040          STORESEQ-1=MPCR                                           04550C00 D
0188  81FC 0000 0030 00A0          20=SAR;31=LIT               $MASK FOR P&W FIELDS OF IAW   04560C00 D
0189  4809 E156 4030 00F0          A3 AND LIT =A1              $A1 NOW = P VALUE             04570C00 D
018A  4809 E0C0 8B08 C0F0          A3 R=B,LMAR                 $LIT=ADDRESS OF Y-ADDRESS;A3=0C/W 04580C00 D
018B  3180 0000 0030 0080          YADDR=LIT;5=SAR                                           04590C00 D
018C  A809 2C56 0090 80F0          LIT AND B=SAR;MR1;IF RDC    $GET Y-ADDRESS;SAR=W VALUE    04600C00 D
018D  01F0 0000 0030 C0E0          31=LIT                                                    04610C00 D
018E  AC08 0000 0C30 40F0          WHEN RDC THEN CSAR,BEX      $SAR= NOT W;B=Y ADDRESS       04620C00 D
018F  4809 0018 9C00 00F0          0111 R=A3                   $A3=MASK W BITS LONG          04630C00 D
0190  A809 0C43 0D1C CCF0          B=MAR2,DMI;MR2;IF RDC       $READ (Y);B=DATA WORD         04640C00 D
0191  4809 EC56 0030 C0F0          A3 AND B=MIR                $MIR = MASKED DATA LSB        04650C00 D
0192  AC08 A0C0 0C00 80F0          WHEN RDC THEN A1=SAR,BEX    $B=(Y);SAR = P VALUE          04660C00 D
0193  4809 0C41 8B30 40F0          B C=B,CSAR                  $B=(Y) SHIFTED BY P           04670C00 D
0194  4809 EC40 0F00 00F0          A3 NRI B=BBI                $B=(Y) MASKED OR DATA         04680C0C D
0195  4809 0C41 8080 00F0          B C=MIR                     $MIR=(Y) OR DATA BACK TO POSITION 04690C00 D
0196  9809 0C00 0090 18F0          MW1;IF SAI                                                04700C00 D
0197  9828 0000 0000 C0FC          WHEN SAI THEN JUMP          $WRITE NEW (Y)                04710C00 D
                                STORESEQ:  $SEQ CHAR ADDR.;B=ICW,A3=0C/W/P                 04720C00 D
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0198  9809 0C48 9030 00F0          B R=A3                    $B=ICW;A3=0C/W/P                  04730C00 D
0199  01F0 0000 0000 00A0          20=SAR;31=LIT                                               04740C00 D
019A  9809 E156 9030 00F0          A3 AND LIT=A1             $A1=P-VALUE                       04750C00 D
019B  9809 E000 9000 00F0          A3 R=A3                   $A3=0C/W                          04760C00 D
019C  9000 0000 0000 0000          5=SAR                                                       04770C00 D
019D  9809 E156 0B90 80F0          A3 AND LIT=B,SAR          $B=$AR=W                          04780C00 D
019E  9809 AC5E 9030 40F0          A1-B=A1,CSAR,LMAR         $P-W=P=A1;SAR=COMP W;MAR=Y LOCATOR 04790C00 D
019F  01B0 0000 0030 00E0          YADDR=LIT                                                   04800C00 D
01A0  7409 A0DE 9030 00F0          IF NOT A0V THEN A1-1=A1                                     04810C00 D
01A1  9FC9 2C5E 9030 00F0          IF NST THEN LIT-B=A1;SET LC1  $A1=32-W=P                    04820C00 D
01A2  7409 A0DE 9030 00F0          IF NOT A0V THEN A1-1=A1                                     04830C00 D
01A3  A809 0018 9000 08F0          0111 R=A3;MR1;IF RDC      $A3=MASK W BITS LONG              04840C00 D
01A4  AC00 0000 0C90 C0F0          WHEN RDC THEN BEX         $B=Y-ADDRESS                      04850C00 D
01A5  2FD9 0C46 0D1C 00F0          IF LC1 THEN B+1=MAR2,BMI;SET LC1;SKIP                       04860C00 D
01A6  9809 0C43 0D1C 00F0          B=MAR2,BMI                $B=DATA;MAR2=Y OR Y+1 ADDRESS     04870C00 D
01A7  A809 A0C8 0090 8CF0          A1=SAR;MR2;IF RDC         $SAR=NEW P; READ (Y)              04880C00 D
01A8  AC00 EC56 0C90 00F0          WHEN RDC THEN A3 AND B=MIR,BEX  $B=(Y) SHIFTED BY P         04890C00 D
01A9  9809 EC49 0FB0 C0F0          A3 MRI B=BBI              $B=(Y) MSAKED ORED WITH DATA      04900C00 D
01AA  9809 0C41 0090 00F0          B C=MIR                   $RESTORE TO POSITION AND OUTPUT   04910C00 D
01AB  9809 0000 0C90 1CF0          MW2;IF SAI                                                  04920C00 D
01AC  9C08 A0C1 0090 00F0          WHEN SAI THEN A1 L=MIR,LMAR  $P LEFT JUSTIFIED TO POSITION  04930C00 D
01AD  01AC 0000 0000 0030          IAW=LIT;COMP 20=SAR                                         04940C00 D
01AE  A809 2001 1090 08F0          LIT L=A3;MR1;IF RDC       $READ ADDRESS OF ICW              04950C00 D
01AF  01F0 00C8 0030 C0E0          31=LIT                                                      04960C00 D
01B0  AC08 0000 0C90 C0F0          WHEN RDC THEN BEX,LMAR    $READ HOME ADDRESS OF ICW         04970C00 D
01B1  01C0 00C8 0030 00E0          IAWADDR=LIT               $ADDRESS OF ADDRESS OF IAW        04980C00 D
01B2  A809 EC56 0FB0 00F0          A3 AND B=BBI;MR1;IF RDC   $B=NEW ICW                        04990C00 D
01B3  AC08 0C48 0C90 00F0          WHEN RDC THEN B=MIR,BEX   $MIR=NEW ICW;B=ADDRESS OF OLD ICW 05000C00 D
01B4  9809 0C43 0D1C 00F0          B=MAR2                    $ADDRESS OF OLD ICW               05010C00 D
01B5  9809 0000 0090 1CF0          MW2;IF SAI                                                  05020C00 D
01B6  9828 0000 0090 00F0          WHEN SAI THEN JUMP        $RETURN FROM WHERE CALLED         05030C00 D
01B7  980C 0000 0030 00F8  KSTABLE:  WAIT                                                      05040C00 D
01B8  08A0 0000 0030 00C0          KS1-1=AMPCR. KS2-1=AMPCR. KS3-1=AMPCR                       05050C00 D
01B9  0800 0000 0030 00C0
01BA  08C0 0000 0000 00CC
01BB  08D0 0000 0000 00C0          KS4-1=AMPCR. KS5-1=AMPCR. KS6-1=AMPCR. KS7-1=AMPCR          05060C00 D
01BC  08E0 00C0 0000 00C0
01BD  08F0 0000 0000 00C0
01BE  0C00 0000 0000 00C0

                           KS1:  $(A 15-0)=>Y 15-0                                          05070C0C D
01BF  AC08 0000 0C90 C0F0          WHEN RDC THEN BEX         $Y31-16 UNCHANGED                 05080C00 D
01C0  9809 0C40 0B90 00F0          B R=B                                                       05090C00 D
01C1  9800 0000 0090 0020          16 = SAR                                                    05100C00 D
01C2  9809 0C41 1D90 03F0          B L=A3,BMI                $A3=Y31-16                        05110C00 D
01C3  9809 0C41 0B9C 00F0          B L=B                                                       05120C00 D
01C4  9809 0C40 0B90 00F0          B R=B                                                       05130C00 D
01C5  9809 EC5C 0090 00F0          A3 OR B=MIR               $(A 15-0)=>Y 15-0                 05140C00 D
01C6  0C10 0000 0000 0040          OUTPUT2NORET-1=MPCR                                         05150C00 D
                           KS2:  $(A15-0)=>Y 31-16                                          05160C00 C
01C7  AC08 0000 0C90 00F0          WHEN RDC THEN BEX         $Y 15-0 UNCHANGED                 05170C00 D
01C8  9809 0C41 0B90 00F0          B L=B                                                       05180C00 D
01C9  0800 0000 0090 0020          16 = SAR                                                    05190000 D
01CA  9809 0C40 9D00 00F0          B R=A3,BMI                                                  05200C00 D
01CB  9809 0C41 0D9C 00F0          B L=B                     $A3=Y 15-0                        05210C00 D
01CC  9809 EC5C 1090 C0FC          A3 OR B=A3,MIR                                              05220C00 D
01CD  0C20 00C0 0090 0040          OUTPUT2NORET-1=MPCR                                         05230C00 D
                           KS3:  $(A31-0)=>Y(31-0)                                          05240C00 D
01CE  AC88 0000 0C90 00F0          WHEN RDC THEN BEX                                           05250C00 D
01CF  0C30 00C0 0090 C040          OUTPUT2NORET-1=MPCR                                         05260C00 D
                           KS4:  $(A 7-0)=>Y 7-0                                            05270C00 D
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01D0  AC08 0000 0C30 00F0          WHEN RDC THEN DEX                                          05280C00 D
01D1  0000 0000 0090 0010          B=SAR                                                      05290C00 D
01D2  9809 0C40 0B00 40F0          B R=B,CSAR                                                 05300C00 D
01D3  9809 0C41 1D90 40F0          B L=A3,BMI,CSAR                                            05310C00 D
01D4  9809 0C41 0B00 40F0          B L=B,CSAR                                                 05320C00 D
01D5  9809 0C40 0B00 00F0          B R=B                                                      05330C00 D
01D6  9809 EC5C 1090 00F0          A3 OR B=A3,MIR                                             05340C00 D
01D7  0C4C 0000 0090 0040          OUTPUT2NORET-1=MPCR                                        05350C00 D
                                KS5:  %(A7-0)=>Y15-8                                          05360C00 D
01D8  AC08 2001 1C90 40F0          WHEN RDC THEN LIT L = A3,CSAR,DEX                          05370C00 D
01D9  0FF0 0000 0090 0080          255 = LIT; COMP 8 = SAR                                    05380C00 D
01DA  9809 EC44 1D90 00F0          A3 NRI B=A3,BMI                                            05390C00 D
01DB  9809 0C41 0B90 00F0          B L=B                                                      05400C00 D
01DC  9809 0C40 0B90 00F0          B R=B                                                      05410C00 D
01DD  0000 0000 0090 C020          16=SAR                    %(A7-0) IN B(15-8)               05420C00 D
01DE  9809 EC5C 1090 00F0          A3 OR B=A3,MIR                                             05430C00 D
01DF  0C5C 00C0 0090 0040          OUTPUT2NORET-1=MPCR                                        05440C00 D
                                KS6:  %(A7-0)=>Y23-16                                         05450C00 D
01E0  AC08 2001 1C90 00F0          WHEN RDC THEN LIT L=A3,DEX                                 05460C00 D
01E1  0FFC 0000 0090 00A0          255=LIT;16=SAR                                             05470C00 D
01E2  9809 EC44 1D90 C0F0          A3 NRI B=A3,BMI                                            05480C00 D
01E3  9809 0C41 0B90 00F0          B L = B                                                    05490C00 D
01E4  000C 0000 0090 0010          COMP 24 = SAR                                              05500C00 D
01E5  9809 0C40 0B00 00F0          B R=B                                                      05510C00 D
01E6  9809 EC5C 1C90 00F0          A3 OR B=A3,MIR                                             05520C00 D
01E7  0C6C 0000 0090 0040          OUTPUT2NORET-1=MPCR                                        05530C00 D
                                KS7:  %(A7-0)=>Y31-24                                         05540C00 D
01E8  AC08 0000 0C0C 00F0          WHEN RDC THEN DEX                                          05550C00 D
01E9  9809 0C41 0B90 40F0          B L=B,CSAR                                                 05560C00 D
01EA  0000 0000 0C30 0030          COMP 0 = SAR                                               05570C00 D
01EB  9809 0C40 9D00 00F0          B R=A3,BMI                %A3=Y23-0                        05580C00 D
01EC  9809 0C41 0B90 00FC          B L = B                                                    05590C00 D
01ED  9809 EC5C 1C90 00F0          A3 OR B=A3,MIR                                             05600C00 D
01EE  0C7C 0000 0090 0040          OUTPUT2NORET-1=MPCR                                        05610C00 D
                                %                                                             05620C00 D
                                %                                                             05630C00 D
                                % ********************    SUBR. FOR I/O FUNCTIONS    ********05640C00 D
                                IOOUMPREG:                                                    05650C00 D
01EF  9809 0000 0090 00F0          0 = MIR                                                    05660C00 D
01F0  0C0C 0000 0090 0040          SIGLOADER-1=MPCR                                           05670C00 D
                                IOOUMPADR:  %B=ADDRESS TO PRINT                               05680C00 D
01F1  9809 03C1 1090 00F0          1 L = A3                                                   05690C00 D
01F2  0000 00C0 0030 0020          COMP 16 = SAR                                              05700C00 D
01F3  9809 EF5C 0090 00F0          A3 OR BMAR=MIR            %OUTPUT LAST Y WRITTEN           05710C00 D
01F4  0C90 0000 0090 0040          SIGLOADER-1=MPCR                                           05720C00 D
                                CARDREAD:  %READ A CARD INTO ADDRESS IN B                     05730C00 D
01F5  9809 2001 1C90 00F0          LIT L=A3                  %FUNCTION CODE IS 2/ADDRESS      05740C00 D
01F6  0020 0000 0090 C0A0          2=LIT;COMP 16=SAR                                          05750C00 D
01F7  9809 EC5C 0090 00F0          A3 OR B=MIR                                                05760C00 D
01F8  0CA0 0000 0090 0040          SIGLOADER1-1=MPCR         %NO RETURN                       05770C00 D
                                PRINTLINE:  %PRINT AN OUTPUT BUFFER ADDRESSED IN B            05780C00 D
01F9  9809 2001 1C90 00F0          LIT L=A3                  %FUNCTION CODE IS 7/ADDRESS      05790C00 D
01FA  0070 0000 0090 C0A0          7=LIT; COMP 16=SAR                                         05800C00 D
01FB  9809 EC5C 0C90 00F0          A3 OR B=MIR                                                05810C00 D
01FC  0C0C 0000 0090 0040          SIGLOADER1-1=MPCR                                          05820C00 D
                                DISKREAD:   %READ/WRITE DISK USING INFO AT Y+(B)+(S)           05830C00 D
                                %B=NUMBER OF WORDS                                            05840C00 D
                                %B+1=DISK SECTOR TO BE ACCESSED                               05850C00 D
                                %B+2= 3=>READ; 4=>WRITE                                       05860000 D
                                %B+3=ADDRESS OF BUFFER                                        05870C00 D
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01FD  9809 0C43 001C 00F0          B=MAR2                                                  0508CC00 D
01FE  A809 0000 0000 0CF0          MR2;IF RDC                                              0509CC00 D
01FF  AC08 0F46 0C1C 00F0          WHEN RDC THEN BMAR+1=MAR2,BEX                           0510CC00 D
0200  A809 0C41 1090 0CF0          B L=A3;MR2;IF RDC          $A3=NUM WORDS/0              0511CC00 D
0201  0000 0000 0000 0020          COMP 16=SAR                                             0512CC00 D
0202  AC08 0F46 0C1C 00F0          WHEN RDC THEN BMAR+1=MAR2,BEX                           0513CC00 D
0203  A809 EC5C 1000 0CF0          A3 OR B=A3;MR2;IF RDC      $A3=NUM WORDS/SECTOR         0514CC00 D
0204  AC08 0F46 0C1C 00F0          WHEN RDC THEN BMAR+1=MAR2,BEX                           0515CC00 D
0205  A809 0C41 4090 0CF0          B L=A1;MR2;IF RDC          $A1=3 OR 4/0                 0516CC00 D
0206  AC08 00D8 001C C0F0          WHEN RDC THEN B110=MAR2                                 0517CC00 D
0207  9809 E000 0090 00F0          A3=MIR                                                  0518CC00 D
0208  9809 AC5C 4090 1CF0          A1 OR B=A1;MW2;IF SAI      $A1=3-4/ADDRESS              0519CC00 D
0209  9C00 A0C0 0C90 00F0          WHEN SAI THEN A1=MIR                                    0600CC00 D
020A  0A5C 00C0 0C90 00C0    SIGLOADER1:  IFETCH-1=AMPCR                                   0601CC00 D
                             SIGLOADER:                                                    0602CC00 D
020B  9809 0018 0C1D 00F0          B111=MAR2,CTR                                           0603CC00 D
020C  9809 0008 0000 1CF0          MW2; IF SAI                                             0604CC00 D
020D  1AC8 00C0 0C00 00F0          IF GC2 THEN RESET GC2; STEP ELSE SKIP                   0605CC00 D
020E  49C9 0008 0000 00FC          SET LC1                    $SIGNALS GC2 MUST BE RESET   0606CC00 D
020F  9848 00C0 0C30 00F0          WHEN SAI THEN RESET GC1                                 0607CC00 D
0210  0AC0 0008 0002 00F0          INC;WHEN COV THEN RESET GC2;STEP                        0608CC00 D
0211  0908 0008 0000 00F0          SET GC1;WHEN GC1 THEN STEP                              0609CC00 D
0212  280D 0008 0000 00F0          IF LC1 THEN STEP ELSE JUMP                              0610CC00 D
0213  10A8 0008 0000 00F0          SET GC2; WHEN GC2 THEN JUMP                             0611CC00 D
                             $                                                             0612CC00 D
                             ERRORMSG:  SD=NUMBER OF ERROR MESSAGE TO BE PRINTED           0613CC00 D
                                    $0=ILLEGAL INSTRUCTION                                 0614CC00 D
                                    $1=INSTRUCTION NOT IMPLEMENTED                         0615CC00 D
                                    $2=SQUARE ROOT OF NEGATIVE NUMBER                      0616CC00 D
0214  9809 0C41 0B90 00F0          B L=B                      $PRINT ERROR MESSAGE         0617CC00 D
0215  0050 0008 0090 00A0          16=SAR;5=LIT                                            0618CC00 D
0216  9809 2C5D 0000 00F0          LIT OR B C=MIR             $MIR= 5/B                    0619CC00 D
0217  20A0 0008 0090 0060          SIGLOADER-1=CPCR                                        0620CC00 D
0218  9809 C0C1 0B90 00F0          A2 L=B                                                  0621CC00 D
0219  0060 0008 0090 00E0          6=LIT                      $OUTPUT ADDRESS AND CONTENTS 0622CC00 D
021A  3819 2C5B 0090 00FC          LIT OR B C=MIR;IF LC2 THEN SKIP                         0623CC00 D
021B  2090 00C0 C090 0040          SIGLOADER1-1=MPCR          $RETURNS TO IFETCH           0624CC00 D
021C  0BC0 0008 0090 C0C0          HALFFETCH=AMPCR                                         0625CC00 D
021D  20A0 0008 0090 0040          SIGLOADER-1=MPCR           $RETURNS TO HALFFETCH        0626CC00 D
021E  9818 0008 0B90 00F0    ILLEGAL:  0=B;SKIP               $RETURNS VIA IFFETCH         0627CC00 D
021F  9849 0008 0B90 00F0    ILLEGAL4:   0=B;SET LC2          $PRINT ILLEGAL INSTRUCTION   0628CC00 D
0220  2130 0008 0090 0040          ERRORMSG-1=MPCR            $ILLEGAL TYPE IV;RETURN TO HALFFETCH 0629CC00 D
0221  985B 2008 0B00 00F0    ILLEGALCHR1:  LIT=B;SET LC2;SKIP                              0630CC00 D
0222  9809 2008 0B90 00F0    ILLEGALCHR:  LIT=B                                            0631CC00 D
0223  0030 0008 0090 C0E0          3=LIT                      $ERROR 3=>ILLEGAL CHR REFERENCE 0632CC00 D
0224  2130 00C0 0090 0040          ERRORMSG-1=MPCR                                         0633CC00 D
0225  9818 00C0 0B90 00F0    UNWRITTEN:  1=B;SKIP                                          0634CC00 D
0226  9849 00C0 0B00 00F0    UNWRITTEN4:  1=B;SET LC2         $PRINT INSTRUCTION NOT IMPLEMENTED 0635CC00 D
0227  2130 0008 0090 0040          ERRORMSG-1=MPCR            $PRINT AND RETURN TO HALFFETCH 0636CC00 D
                             $                                                             0637CC00 D
                             $ ********************    SUBR. FOR REGISTER STORES    ********** 0638CC00 D
                             PUTPAR:                         $SAVE CONTENTS OF PAR REGISTER IN B 0639CC00 D
0228  9809 C000 0038 C0F0          A2=MIR,LMAR                                             0640CC00 D
0229  01DC 0008 0090 C0E0          PAR=LIT                                                 0641CC00 D
022A  0CCC 00C8 0090 0040          OUTPUT1-1=MPCR                                          0642CC00 D
                             GETPAR:                         $RESTORE CONTENTS OF PAR FROM B 0643CC00 D
022B  9809 0008 0C38 00F0          LMAR                                                    0644CC00 D
022C  01DC 0008 0000 00E0          PAR=LIT                                                 0645CC00 D
022D  A809 0008 0090 00FC          MR1;IF RDC                                              0646CC00 D
022E  AC08 0008 0CDC 00F0          WHEN RDC THEN BEX                                       0647CC00 D
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022F  482D 0C40 2050 00F0          B=A2;JUMP                                                          06480C00 D
                                OUTPUT:   $NO RETURN                                                 06490C00 D
0230  0A50 0000 0080 00C0          IFETCH-1=AMPCR                                                     06500000 D
0231  9809 0000 0000 10F0       OUTPUT1:  MW1;IF SAI                                                  06510C00 D
0232  9C20 0000 0000 00F0          WHEN SAI THEN 0;JUMP                                               06520C00 D
0233  0A50 0000 0050 00C0       OUTPUT2NORET:  IFETCH-1=AMPCR                                         06530C00 D
0234  9809 0000 0090 1CF0       OUTPUT2:  MW2;IF SAI                                                  06540C00 D
0235  9C00 0000 0000 00F0          WHEN SAI THEN 0;STEP                                               06550C00 C
0236  D80D 0000 0050 00F0          IF IRQ THEN STEP ELSE JUMP                                         06560C00 D
0237  1F00 0000 0050 0040          IODUMPADR-1=MPCR                                                   06570C00 D
                                YOUT:     $Y-ADDRESS IN MAR2 CAME FROM PRECALCULATED EXCEPT REP      06580C00 D
0238  1C19 C000 9050 00F0          IF GC2 THEN A2 R=A3;SKIP   $REPLACE REPEAT IS SPECIAL              06590000 D
0239  2320 00C0 0050 0040          OUTPUT2NORET-1=MPCR                                                06600C00 D
023A  0180 0000 0C50 00A0          20=SAR;YADDR=LIT                                                   06610C00 D
023B  9809 E000 0050 00F0          A3                                                                 06620C00 D
023C  5C19 0000 0000 00F0          IF LST THEN LMAR;SKIP      $CHECK FOR REPEAT INSTR. MODE           06630C00 D
023D  2320 00C0 0050 0040          OUTPUT2NORET-1=MPCR                                                06640C00 D
023E  A809 0000 0050 C0F0          MR1;IF RDC                 $READ Y-ADDRESS                         06650C00 D
023F  AC00 00C0 0C50 00F0          WHEN RDC THEN BEX                                                  06660C00 D
0240  3C09 0C40 0C1C 00F0          IF LC2 THEN B=MAR2                                                 06670C00 D
0241  2320 00C0 0050 0040          OUTPUT2NORET-1=MPCR                                                06680C00 D
                                $ ########################     LOGICAL SUBROUTINES          ########06690C00 D
                                OUTLOGIC:                      $Y ADDRESS IN B,A ADDR IN MAR1          06700C00 D
0242  2A59 0000 0050 00F0          IF LC1 THEN SET LC2;SKIP                                           06710C00 D
0243  22F0 0000 0000 0040          OUTPUT-1=MPCR              $OPCODE01=>  NO RETURN                  06720C00 D
0244  2300 0000 0000 006C          OUTPUT1-1=CPCR             $OPCODE 02 => RETURN                    06730C00 D
0245  9809 A002 001C 00F0          A1=MAR2                    $SAVE Y-ADDRESS IN A1                   06740C00 D
0246  2370 0000 0090 004C          YOUT-1=MPCR                $OUTPUT TO Y ADDRESS                    06750C00 D
0247  9809 A000 9000 00F0       GETF:     A1 R=A3            $ISOLATE AND RETURN F FIELD             06760000 D
0248  8070 0000 0050 00A0          20=SAR;7=LIT                                                       06770C00 D
0249  482D E156 1050 00F0          A3 AND LIT=A3;JUMP                                                 06780C00 D
024A  9809 A0C0 8B50 00F0       GETAB:    A1 R=B             $ISOLATE AND RETURN IN B & MAR A-FLD     06790C00 D
024B  8070 0000 0050 00A0          23=SAR;7=LIT                                                       06800000 D
024C  482D 2C56 0B0C 00F0          LIT AND B=B,MAR;JUMP                                               06810C00 D
024D  9809 A000 9050 00F0       GETAA3:   A1 R=A3            $ISOLATE AND RETURN IN A3&MAR A-FIELD    06820C00 D
024E  8070 0003 0050 00A0          23=SAR;7=LIT                                                       06830000 D
024F  482D E156 109C 00F0          A3 AND LIT=A3,MAR;JUMP                                             06840C00 D
                                GETF1:                         $RETURNS F1 FIELD FOR TYPE 3 IN A3      06850C00 D
0250  9809 A000 9050 00F0          A1 R=A3                                                            06860000 D
0251  9030 0000 0000 00A0          21=SAR;3=LIT                                                       06870000 D
0252  482D E156 1000 00F0          A3 AND LIT=A3;JUMP                                                 06880C00 D
                                CHECKCMR:  $CMR ADDRESS IN A3;LC1 SET IF PRIVILEGED;RETURN LC1 IF LEGAL 06890000 D
0253  9809 E15E 0050 00F0          A3 LSS LIT                 $CHECK ADDR LT 20 OCTAL                 06900C00 D
0254  0100 0000 0000 00EC          16=LIT                                                             06910C00 D
0255  73E9 0000 0C50 00F0          IF TRUE THEN SET LC1; JUMP                                         06920C00 D
0256  9809 E15E 0050 C0F0          A3 LSS LIT                 $CHECK ADDRESS LT 30 OCTAL              06930000 D
0257  0180 00C0 0050 00E0          24=LIT                     $CHECH A:DR LT 30 OCTAL                 06940000 D
0258  7C19 E15E 0C50 00FC          IF FALSE THEN A3 LSS LIT; SKIP                                     06950C00 D
0259  28ED 0000 0050 00F0          JUMP; IF LC1 THEN SET LC1                                          06960C00 D
025A  0300 0000 0000 00E0          48=LIT                     $CHECK ADDR LT 60 OCTAL                 06970C00 D
025B  7C19 E15E 0C50 00F0          IF FALSE THEN A3 LSS LIT;SKIP                                      06980C00 D
025C  282D 00C0 0050 00FC          JUMP; IF LC1                                                       06990C00 D
025D  0500 0000 0000 00E0          80=LIT                                                             07000C00 D
025E  7C19 E15E 0050 C0F0          IF FALSE THEN A3 LSS LIT;SKIP                                      07010C00 D
025F  28ED 00C0 0C50 00F0          JUMP; IF LC1 THEN SET LC1                                          07020C00 D
0260  0600 0000 0050 00E0          96=LIT                                                             07030C00 D
0261  7C19 E15E 005C 00F0          IF FALSE THEN A3 LSS LIT;SKIP                                      07040C00 D
0262  282D 0000 0050 00F0          JUMP; IF LC1                                                       07050C00 D
0263  280C 0000 0050 C090          128=LIT;10=SAR                                                     07060C00 D
0264  7019 0003 0050 00F0          IF TRUE THEN SKIP                                                  07070C00 D
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0265  282D 0000 0000 00F0          JUMP; IF LC1                                                    07080000 D
0266  28ED 0000 0000 00F0          JUMP;IF LC1 THEN SET LC1                                        07090000 D
                                 $ ########################     JUMP SUBROUTINES          ############07100000 D
                                 PUTJUMP:    $A3=JUMP ADDRESS;STORE IN A3&PAR                     07110000 D
0267  2C19 C000 A000 00F0          IF LC1 THEN A2 R=A2;SKIP                                        07120000 D
0268  0A50 0000 0000 0040          IFETCH-1=MPCR              $NO JUMP IF NOT LC1                  07130000 D
0269  000C 0000 0000 0020          16=SAR                                                          07140000 D
026A  3809 C001 0B30 00F0          A2 L=B;IF LC2                                                   07150000 D
026B  4809 EC5C 2000 00F0          A3 OR B=A2                 $UPDATE PAR                          07160000 D
026C  2270 0000 0000 0060          PUTPAR-1=CPCR              $WRITE TO PAR LOCATION AND RETURN    07170000 D
026D  0A50 0000 0000 0040          IFETCH-1=MPCR                                                   07180000 D
                                 $                                                                 07190000 D
                                 $                                                                 07200000 D
                                 $ ########################     SHIFT SUBROUTINES         ############07210000 D
                                 SHIFTAMOUNT:   $RETURNS B=(A-REG);MAR=A-ADDR.;SAR=SHIFTAMOUNT     07220000 D
026E  4809 A001 1000 00F0          A1 L=A3                                                         07230000 D
026F  2000 0000 0030 0030          COMP 6=SAR                 $DROP OPCODE FIELD                   07240000 D
0270  4809 E000 9000 00F0          A3 R=A3                    $ISOLATE A/M FIELDS IN LOW 10 BITS   07250000 D
0271  A000 00C0 0030 0020          22=SAR                                                          07260000 D
0272  4809 E156 B03C 00F0          A3 AND LIT R=MAR           $MASK B-FIELD INTO MAR               07270000 D
0273  10E0 0000 0030 0080          14=LIT;1=SAR                                                    07280000 D
0274  4809 E156 0B00 00F0          A3 AND LIT R=B             $B=BITS 5&6                          07290000 D
0275  960C 0000 0030 0080          96=LIT;5=SAR               $MASK FOR BITS 5&6                   07300000 D
0276  4809 2C52 0C00 20FC          LIT EQL B;ASR                                                   07310000 D
0277  0020 0000 0000 00E0          2=LIT                      $2=> SHIFT AMOUNT IN B(B)            07320000 D
0278  6FC9 2F40 003C 00F0          IF TRUE THEN LIT+BMAR=MAR;SET LC1                               07330000 D
0279  008C 000B 0000 C0E0          BBASE=LIT                                                       07340000 D
027A  A809 2C52 0030 00F0          LIT EQL B;IF RDC                                                07350000 D
027B  0030 0000 003C 00E0          3=LIT                      $3=> SHIFT AMOUNT IN A(B)            07360000 D
027C  6BC9 00C0 0000 00F0          IF TRUE THEN SET LC1       $MAR SETUP FOR A(B)                  07370000 D
027D  2A0B 0000 0000 C0F0          IF LC1 THEN MR1;STEP ELSE SKIP                                  07380000 D
027E  AC18 0000 0C30 00F0          WHEN RDC THEN BEX;SKIP     $B=A(B) OR B(B)                      07390000 D
027F  4809 E156 0B00 00F0          A3 AND LIT=B               $B=M-FIELD                           07400000 D
0280  B3F0 0000 0030 0080          63=LIT;7=SAR               $MASK M-FIELD OF 63                  07410000 D
0281  4809 E000 B03D 00F0          A3 R=MAR;CTR               $SAVE A-ADDRESS IN CTR               07420000 D
0282  A809 2C56 1000 00F0          LIT AND B=SAR;A3;MR1;IF RDC                                     07430000 D
0283  4809 E15E C000 00F0          A3 GEQ LIT                                                      07440000 D
0284  0200 0000 003C C0E0          32=LIT                                                          07450000 D
0285  7FC9 E15E 0000 80F0          IF TRUE THEN A3-LIT=SAR;SET LC1                                 07460000 D
0286  AC28 00C0 0C00 00F0          WHEN RDC THEN BEX;JUMP     $B=(A-REG);MAR=A-ADDR;EAR=SHIFT AMT. 07470000 D
                                 $                                                                 07480000 D
                                 $                                                                 07490000 D
                                 $ ########################     COMPARE SUBROUTINES       ############07500000 D
                                 SETCOMPARE:    $COMPARE A(B) WITH A(A)  AND SET CD BITS          07510000 D
0287  0BCC 00C0 C000 00C0          HALFFETCH=AMPCR                                                 07520000 D
0288  280B 00C0 0000 00F0          IF LC1 THEN STEP ELSE SKIP $LC1=> CALLED BY OPR 44,46,47        07530000 D
0289  0A50 0000 0030 00C0          IFETCH-1=AMPCR             $ELSE OPR 74X4,6,7                   07540000 D
                                 SETCDRET:  $ENTER HERE AND RETURN WHERE CALLED FROM               07550000 D
028A  4849 EC52 0000 00F0          A3 EQL B;SET LC2           $EQUALITY CK;SETUP FOR REPEAT        07560000 D
028B  6C19 D01D A030 40F0          IF TRUE THEN A2 OR B100 C=A2,CSAR;SKIP  $SET EQUAL BIT          07570000 D
028C  4809 D80F AC30 40F0          A2 AND B011 C=A2,CSAR      $CLEAR EQUAL BIT                     07580000 D
                                   $GREATER THEN EQUAL TO BIT NOW IN MSB                           07590000 D
028D  B000 0000 0C30 0030          31=SAR                                                          07600000 D
028E  4809 EC4C 0000 00F0          A3 XOR B                                                        07610000 D
028F  4808 EC5E 0000 00F0          A3 LSS B; IF MST THEN STEP ELSE SKIP                            07620000 D
0290  7C28 D80F AC30 00F0          IF FALSE THEN A2 AND B011 C = A2; JUMP ELSE SKIP                07630000 D
0291  7429 D80F A030 00F0          IF TRUE THEN A2 AND B011 C=A2;JUMP                              07640000 D
0292  482D D01D A000 C0FC          A2 OR B100 C=A2;JUMP                                            07650000 D
                                   $A2 RESTORED TO NORMAL BEFORE EXIT TO WHERE CALLED FROM        07660000 D
                                 $                                                                 07670000 D
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                                 $
                                 $ ************************    BIT COUNT SUBROUTINE        *************
                                 COUNTONES:   $COUNT NUMBER OF ONES IN B AND RETURN COUNT IN A3,MIR
0293  4009 0000 1031 00F0                0=A3,LCTR
0294  11FC 0000 0000 0080                31=LIT;1=SAR
0295  4009 0C41 8002 00F0        CHECKLSB:  B C=B,INC
0296  5C09 E0C0 1030 00F0                IF LST THEN A3+1=A3,MIR
0297  8029 00C0 0030 00F0                IF COV THEN JUMP
0298  294C 0000 0030 0040                CHECKLSB-1=MPCR
                                 $
                                 $
                                 $ ************************    MULTIPLY SUBROUTINE         *************
                                 MULTIPLY:  $A2 AND B CONTAIN OPERATORS
0299  4009 0000 5001 00F0                0=A1,A3,LCTR
029A  11F0 0000 0030 0080                31=LIT;1=SAR
029B  2009 0C52 0000 00F0                0 EOL B;IF LC1            $TEST FOR ZERO MULTIPLY
029C  640D CC4C 0C00 00F0                IF FALSE THEN A2 XOR B;STEP ELSE  JUMP
029D  40C9 C000 0C30 00F0                A2;IF MST THEN SET LC1     $TEST FOR DIFFERENT SIGNS
029E  4C09 C002 2000 00F0                IF MST THEN NOT A2=A2      $TEST FOR NEGATIVE
029F  4009 0C40 0C00 00F0                B                          $TEST FOR NEGATIVE
02A0  4C09 0C42 000C 00F0                IF MST THEN NOT B=B
02A1  4009 C000 A032 00F0        MULT1:  A2 R=A2,INC
02A2  5C19 AC40 C000 00F0                IF LST THEN A1+B R=A1;SKIP $A1=MOST SIGNIFICANT
02A3  4009 A000 C000 00F0                A1 R=A1
02A4  5C09 F81C 1C00 00F0                IF LST THEN A3 OR B100=A3  $A3=LEAST SIGNIFICANT
02A5  8406 E000 9000 C0F0                IF NOT COV THEN A3 R=A3;STEP ELSE SKIP
02A6  2A00 0000 000C 0040                MULT1-1=MPCR
02A7  2C0D E002 1000 00F0                IF LC1 THEN NOT A3=A3;STEP ELSE JUMP
02A8  402D A002 4030 00F0                NOT A1=A1;JUMP
                                 $
                                 $
                                 $ ************************    DIVIDE SUBROUTINE           *************
                                 DIVIDE:  $B=DIVISOR; A3=MOST DIVIDEND; MAR=LEAST DIVIDEND ADDRESS
02A9  4049 0000 6001 00F0                0=A1,A2,LCTR;SET LC2       $0=>A2; REM.=>A1
02AA  91E0 0000 0030 0080                30=LIT;COMP 1=SAR
02AB  4009 0C52 0000 C0F0                B EOL 0
02AC  6BE9 E0C0 0030 C0F0                A3; IF TRUE THEN SET LC1;JUMP $OVERFLOW=>DIVISION BY ZERO
02AD  4FC9 E002 1000 00F0                IF MST THEN NOT A3=A3;SET LC1
C2AE  A009 0C40 0030 00F0                B;MR1;IF RDC               $READ LEAST DIVIDEND
02AF  4C09 1458 0800 00F0                IF MST THEN BTFF=B         $DIVISOR NEGATIVE
C2B0  4009 E001 1000 00F0        DIV1:  A3 L=A3
02B1  4C09 A0DC 4030 00F0                IF MST THEN A1 OR B001=A1
02B2  4009 A45E 0C00 00F0                A1 LSS BOTT
02B3  7C0B C0DC 2030 C0FC                IF FALSE THEN A2 OR B001=A2;STEP ELSE SKIP
02B4  4009 A45E 4030 C0F0                A1-BOTT=A1
02B5  8019 00C0 0002 C0F0                INC;IF NOT COV THEN SKIP
02B6  0CDC 0000 0000 0040                DIV2-1=MPCR
02B7  4009 A001 4030 00F0                A1 L=A1
02B8  4009 C001 2030 00F0                A2 L=A2
02B9  40E9 0000 0030 00F0                IF MST THEN SET LC1;JUMP
02BA  2AFC 0000 003C 0040                DIV1-1=MPCR
C2BB  3C19 C0C1 2001 00F0        DIV2:  IF LC2 THEN A2 L=A2,LCTR;SKIP
C2BC  0CE0 0000 0000 004C                DIV3-1=MPCR
02BD  4009 0C40 1000 00F0                B=A3
02BE  AC08 A001 4C30 C0F0                WHEN RDC THEN A1 L=A1,BEX  $B=LEAST DIVIDEND
02BF  4009 EC4C 1000 00F0                A3 XOR B=A3                $SWAP B AND A3
02C0  4009 EC4C 0800 C0F0                A3 XOR B=B
02C1  4009 EC4C 1C30 C0F0                A3 XOR B=A3
02C2  2FC9 E002 1000 00F0                IF LC1 THEN NOT A3=A3;SET LC1
02C3  2AFC 0000 0030 0040                DIV1-1=MPCR
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02C4  4809 CC40 009C 00F0      DIV3:  B                                %QUOTIENT IN A2;REM IN A1                0828CC00 D
02C5  4019 0008 0090 00F0             IF NOT MST THEN SKIP                                                      0829CC00 D
02C6  0CF0 0000 0C90 0040             DIVNEG-1=MPCR                                                             0830CC00 D
02C7  2C0D C002 2090 C0F0             IF LC1 THEN NOT A2=A2;STEP ELSE JUMP                                      0831CC00 D
02C8  482D A002 4090 C0F0             NOT A1=A1;JUMP                                                            0832CC00 D
02C9  2C29 A002 4090 00F0      DIVNEG:  IF LC1 THEN NOT A1=A1;JUMP                                              0833CC00 D
02CA  482D C002 2090 C0F0             NOT A2=A2;JUMP                                                            0834CC00 D
                               %                                                                                0835CC00 D
                               %                                                                                0836CC00 D
                               % ******ROUTINES FOR REPEAT AND INDIRECTION CONTROL **************               0837CC00 D
                               GC2CHECK:                               % GC2 IS SET                              0838CC00 D
02CB  4809 C201 1C00 00F0             A2 L = A3                                                                 0839CC00 D
02CC  A000 0C00 0000 0020             COMP 10=SAR                       %CHECK BIT 21=REPEAT BIT                0840CC00 D
02CD  4809 E00B 0090 00F0             A3                                                                        0841CC00 D
02CE  4808 0000 0C0C 00F0             IF MST THEN STEP ELSE SKIP     % CHECK FOR REPEAT MODE                    0842CC00 D
02CF  0000 0000 0C90 0060             RPTCHECK-1 = CPCR                                                         0843CC00 D
                               GC2CHECK1:                                                                       0844CC00 D
02D0  3809 2001 0800 00F0             LIT L = B; IF LC2                                                         0845CC00 D
02D1  3070 0009 0090 0090             7 = LIT; COMP 21 = SAR                                                    0846CC00 D
02D2  48C9 CC4E 2090 00F0             A2 NIM B = A2; RESET GC2   % CLEAR A2(23-21)                              0847CC00 D
02D3  0AA0 0008 0090 0040             IFETCH1- 1 = MPCR                                                         0848CC00 D
                               RPTCHECK:                                                                        0849CC00 D
02D4  4809 00C0 0098 00F0             LMAR                              % B(7)                                  0850CC00 D
02D5  00F0 0000 0090 00E0             15 = LIT                                                                  0851CC00 D
02D6  A809 00C0 0000 C8F0             MR1; IF RDC                                                               0852CC00 D
02D7  AC08 0008 0C90 00F0             WHEN RDC THEN BEX                                                         0853CC00 D
02D8  4809 0C42 0090 00F0             NOT B                                                                     0854CC00 D
02D9  640D 0C40 1000 00F0             IF NOT ABT THEN B=A3;STEP ELSE JUMP  %(B(7))=C,RETURN GCCHECK             0855CC00 D
02DA  4809 E00E 0090 00F0             A3-1 = MIR                                                                0856CC00 D
02DB  230C 0008 0090 0060             OUTPUT1-1 = CPCR                  % DEC B(7)                              0857CC00 D
02DC  4809 0008 0098 00F0             LMAR                                                                      0858CC00 D
02DD  0180 00C0 0090 00E0             RINST=LIT                         %REPEAT INSTR.                          0859CC00 D
02DE  A809 00C0 0000 08F0             MR1; IF RDC                                                               0860CC00 D
02DF  AC08 00C0 0C90 00F0             WHEN RDC THEN BEX                 % REPEAT INST.                          0861CC00 D
02E0  4809 0C40 C090 00F0             B R=A1,MIR                                                                0862CC00 D
02E1  B070 0008 0000 00A0             7 = LIT; 23 = SAR                                                         0863CC00 D
02E2  4809 A156 4090 00F0             A1 AND LIT = A1                   % A-FIELD                               0864CC00 D
02E3  0D10 0000 0090 00C0             ACMP0-1 = AMPCR                   % CHECK A-FIELD                         0865CC00 D
02E4  3829 0000 0090 00F0             IF LC2 THEN JUMP                  % FOR TERMINATE                         0866CC00 D
02E5  0D20 0000 0090 0040             ANCMP0-1 = MPCR                   % CONDITIONS                            0867CC00 D
02E6  4809 0000 0098 00F0      RPTCHECK1:  LMAR                                                                 0868CC00 D
02E7  018C 00C0 0C90 00E0             RINST=LIT                                                                 0869CC00 D
02E8  A809 00C0 0000 08F0             MR1;IF RDC                                                                0870CC00 D
02E9  AC08 00C0 0C90 00FC             WHEN RDC THEN BEX                                                         0871CC00 D
02EA  4809 0C41 0B38 00F0             B L = B,LMAR                                                              0872CC00 D
02EB  0190 0000 0C00 00A0             CINST=LIT;16=SAR                  %CURRENT INSTR.                         0873CC00 D
02EC  A809 0C40 0090 08FC             B;MR1;IF RDC                                                              0874CC00 D
02ED  4C19 0018 C000 00F0             IF MST THEN B111 R=A1;SKIP                                                0875CC00 D
02EE  4809 0000 4000 00F0             0=A1                                                                      0876CC00 D
02EF  AC08 AC5D 8C80 00F0             WHEN RDC THEN A1 OR B C=MIR,BEX                                           0877CC00 D
02F0  4809 0C40 4000 00FC             B = A1                            % RESTORE C.I.                          0878CC00 D
02F1  4809 A008 9000 00F0             A1 R = A3                                                                 0879CC00 D
02F2  1070 00C0 0090 00A0             7 = LIT; 17 = SAR                                                         0880CC00 D
02F3  4809 E156 1D3C 00F0             A3 AND LIT = A3,BMI               % B-FIELD                               0881CC00 D
02F4  4809 E140 003C 00F0             A3 + LIT = MAR                                                            0882CC00 D
02F5  0080 0000 0090 00E0             BBASE = LIT                                                               0883CC00 D
02F6  A809 0000 0000 68F0             MR1; IF RDC                                                               0884CC00 D
02F7  AC08 0C40 1C80 00F0             WHEN RDC THEN B = A3,BEX                                                  0885CC00 D
02F8  4809 EC40 0090 00F0             A3 + B = MIR                                                              0886CC00 D
02F9  2300 00C0 0090 0060             OUTPUT1-1 = CPCR                  % B(B)+SY=>B(B)                         0887CC00 D
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02FA  4809 0000 0038 00F0          LMAR                                                    08880000 D
02FB  0180 0000 0000 00E0          YADDR=LIT                                               08890000 D
02FC  A809 0000 0C90 08F0          MR1; IF RDC                                             08900000 D
02FD  AC08 0000 0C90 00F0          WHEN RDC THEN BEX          % Y=Y+B(B)+S(6)              08910000 D
02FE  4809 EC40 0030 00F0          A3 + B = MIR               % Y + SY = Y                 08920000 D
02FF  2300 0000 0030 0060          OUTPUT1-1 = CPCR                                        08930000 D
0300  0830 0000 0000 0040          IFETCH2 -1 = MPCR                                       08940000 D
                            S6YFETCH:                         % Y,S,B => A1               08950000 D
0301  4809 0640 0030 00FC          AMPCR = MIR                                             08960000 D
0302  4809 A000 9030 00F0          A1 R = A3                                               08970000 D
0303  1070 0000 0000 00A0          7 = LIT; 17 = SAR                                       08980000 D
0304  4809 E156 1030 00F0          A3 AND LIT = A3                                         08990000 D
0305  4809 E140 003C 00F0          A3 + LIT = MAR             % B(B)                       09000000 D
0306  0080 0000 0030 00E0          BBASE = LIT                                             09010000 D
0307  A809 A001 0B00 48F0          A1 L = B,CSAR; MR1; IF RDC                              09020000 D
0308  9160 0000 0030 0090          S6=LIT;COMP 19=SAR                                      09030000 D
0309  AC08 0C40 9C30 00F0          WHEN RDC THEN B R = A3,BEX   % B(B) => B                09040000 D
030A  4809 EC40 1008 00F0          A3 + B = A3,LMAR             % Y +B(B)=> A3, S(6)=>MAR   09050000 D
030B  A809 0000 0030 08F0          MR1; IF RDC                                             09060000 D
030C  0180 0000 0030 00E0          YADDR=LIT                                               09070000 D
030D  AC08 0000 0C0C 00F0          WHEN RDC THEN BEX          % S(6)=>B                    09080000 D
030E  4809 EC40 0D98 C0F0          A3+B=MIR,BMI,LMAR          %MIR=Y+B(B)+S(6)             09090000 D
030F  2300 0000 0030 0060          OUTPUT1-1 = CPCR           % STORE Y AT 19              09100000 D
0310  4809 0C40 0040 00F0          B = AMPCR                                               09110000 D
0311  4809 0000 0000 00F0          STEP                                                    09120000 D
0312  482D 0000 0030 00F0          JUMP                                                    09130000 D
                            FETNORM:                                                      09140000 D
0313  4809 A000 9000 00F0          A1 R = A3                                               09150000 D
0314  1070 0000 0000 00A0          7 = LIT; 17 = SAR                                       09160000 D
0315  4809 E156 1030 00F0          A3 AND LIT = A3                                         09170000 D
0316  4809 E140 003C 00F0          A3 + LIT = MAR             % B(B)                       09180000 D
0317  0080 0003 0000 00E0          BBASE = LIT                                             09190000 D
0318  A809 A001 0B00 48F0          A1 L = B,CSAR; MR1; IF RDC                              09200000 D
0319  91F0 0000 0000 0090          31 = LIT; COMP 19 = SAR                                 09210000 D
031A  AC08 0C40 9C00 00F0          WHEN RDC THEN B R = A3,BEX    % Y=>A3,B(B)=>B           09220000 D
031B  4809 EC40 1000 00F0          A3 + B = A3                % Y + B(B)=>A3               09230000 D
031C  4809 A000 8B00 00F0          A1 R = B                                                09240000 D
031D  9070 0000 0030 0090          7 = LIT; 13 = SAR                                       09250000 D
031E  4809 2C56 0B30 00F0          LIT AND B = B              % S-FIELD                    09260000 D
031F  4809 2C40 000C C0F0          LIT + B = MAR              % S(S)                       09270000 D
0320  0100 0000 0000 00E0          SBASE = LIT                                             09280000 D
0321  A809 0000 0C90 08F0          MR1; IF RDC                                             09290000 D
0322  AC08 0000 0C90 00F0          WHEN RDC THEN BEX                                       09300000 D
0323  482D EC40 101C 00F0          A3 + B = A3,MAR2;JUMP                                   09310000 D
                            FETCHOPTO:                                                    09320000 D
0324  4809 A000 9030 00F0          A1 R = A3                                               09330000 D
0325  1070 0000 0030 00A0          7 = LIT; 17 = SAR                                       09340000 D
0326  4809 E156 1030 00F0          A3 AND LIT = A3            % B-FIELD                    09350000 D
0327  4809 E140 003C 00F0          A3 + LIT = MAR             % S(B)                       09360000 D
0328  0100 0003 0030 00A0          SBASE = LIT; 16 = SAR                                   09370000 D
0329  A809 A001 1030 08F0          A1 L = A3; MR1; IF RDC                                  09380000 D
032A  AC08 E000 9C30 00F0          WHEN RDC THEN A3 R = A3,BEX    % SY => A3               09390000 D
032B  482D EC40 101C 00F0          A3 + B = A3,MAR2; JUMP     % SY + S(B)                 09400000 D
                            FETCHOPT1:                                                    09410000 D
032C  4809 A000 9030 C0F0          A1 R = A3                                               09420000 D
032D  1070 0000 0000 00A0          7 = LIT; 17 = SAR                                       09430000 D
032E  4809 E156 1000 00F0          A3 AND LIT = A3            % B-FIELD                    09440000 D
032F  4809 E140 0C3C 00F0          A3 + LIT = MAR             % B(B)                       09450000 D
0330  0080 0000 0000 00A0          BBASE = LIT; 16 = SAR                                   09460000 D
0331  A809 A001 0B00 08F0          A1 L = B; MR1; IF RDC                                   09470000 D
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0332  AC06 0C48 0C80 00F0          WHEN RDC THEN B R = MIR,BEX    % SY => MIR                  09480C00 D
0333  9809 E140 003C 00F0          A3 + LIT = MAR                 % S(B)                       09490000 D
0334  0100 0000 0000 00E0          SBASE = LIT                                                09500000 D
0335  A809 0C40 1D00 08F0          B = A3,BMI; MR1; IF RDC        % B(B)=>A3,SY=>B             09510C00 D
0336  AC08 EC40 1C80 00F0          WHEN RDC THEN A3 + B = A3,BEX                              09520C00 D
0337  9820 EC40 101C 00F0          A3 + B = A3,MAR2; JUMP         % SY+B(B)+S(B)               09530C00 D
                                INDIRECT:                                                    09540000 D
0338  9809 A000 9C00 00F0          A1 R = A3                      % OPCODE                     09550C00 D
0339  2300 0000 0030 00B0          48=LIT;26=SAR                                              09560000 D
033A  9809 E15E 0000 00F0          A3 LSS LIT                                                 09570C00 D
033B  7019 0000 0030 00F0          IF TRUE THEN SKIP                                          09580C00 D
033C  0B3C 0000 0000 C040          IFETCH2-1 = MPCR               % HALF-WORD INST             09590C00 D
                                INDIRECT1:                                                   09600000 D
033D  3120 0000 0000 0060          FETNORM-1 = CPCR               % Y=Y+B(B)+S(S)              09610C00 D
                                INDIRECT2:                                                   09620000 D
033E  A809 A000 C000 9CF0          A1 R = A1,CSAR; MR2; IF RDC    % Y => MAR2                  09630C00 D
033F  8000 C000 0030 0020          20 = SAR                                                   09640C00 D
0340  AC08 A001 9C30 00F0          WHEN RDC THEN A1 L = A1,BEX                                09650C00 D
0341  9809 0C40 0030 40F0          B = MIR, CSAR                  % (Y) = MIR                 09660C00 D
0342  9809 0C41 0B30 40FC          B L = B,CSAR                                               09670C00 D
0343  9809 0C40 0B30 00F0          B R = B                                                    09680000 D
0344  9809 AC5C 9C30 00F0          A1 OR B = A1                   % REPLACE A1(19-0)           09690C00 D
0345  9809 A000 9D00 00F0          A1 R = A3,BMI                  % (Y)=B                      09700C00 D
0346  0000 0000 0000 0020          16 = SAR                                                   09710C00 D
0347  9809 E000 0030 C0F0          A3                                                         09720000 D
0348  5819 0008 0000 C0FC          IF LST THEN SKIP               % A1(16)=1?                 09730C00 D
0349  0D3C 0000 0030 0040          INDIRECT3-1 = MPCR             % A1(16)=0                  09740C00 D
034A  9839 0C40 9030 C0F0          B R = A3                       % A1(16)=1                  09750C00 D
034B  9010 0000 0030 00B0          ONE = LIT; 29 = SAR                                        09760C00 D
034C  9809 E158 0030 00F0          A3 GTR LIT                                                 09770C00 D
034D  7019 0000 0030 00F0          IF FALSE THEN SKIP                                         09780C00 D
034E  33C0 0F00 0030 0040          INDIRECT1-1 = MPCR                                         09790000 D
034F  3280 0000 0000 00C0          FETCHOPT1-1 = AMPCR                                        09800000 D
0350  9809 E000 0030 C0F0          A3                                                         09810C00 D
0351  5033 00C0 0C00 00F0          IF LST THEN CALL ELSE SKIP                                 09820C00 D
0352  981B 000B 0000 C0F0          SKIP                                                       09830C00 D
0353  3230 0000 000C 0060          FETCHOPTO-1 = CPCR                                         09840000 D
0354  3300 0000 0000 0040          INDIRECT2-1 = MPCR                                         09850C00 D
                                INDIRECT3:                     % Y =>MAR2,(Y)=>B,MIR        09860C00 D
0355  9809 00C0 0008 00F0          LMAR                                                       09870C00 D
0356  01A0 0000 0030 00E0          IAW=LIT                                                    09880C00 D
0357  2300 0000 0030 C060          OUTPUT1-1 = CPCR               % SAVE (Y) = ICW            09890000 D
0358  9809 00C0 0008 C0F0          LMAR                                                       09900C00 D
0359  01C0 0000 0000 00E0          IAWADDR=LIT                                                09910C00 D
035A  2300 0000 0030 0060          OUTPUT1-1 = CPCR               % SAVE Y = ADDR ICW         09920C00 D
035B  1819 0000 0000 00F0          IF GC2 THEN SKIP               % REPEAT                    09930C00 D
035C  0040 0000 003C 0040          INDIRECT4-1 = MPCR                                         09940C00 D
035D  3000 0000 0030 0060          S6YFETCH-1 = CPCR              % Y = Y+B(B)+S(6)           09950000 D
035E  9809 A000 0038 00F0          A1 = MIR,LMAR                                              09960C00 D
035F  0190 0000 0000 00E0          CINST=LIT                                                  09970C00 D
0360  2300 0000 0090 0060          OUTPUT1-1 = CPCR               % SAVE C.I.                 09980C00 D
0361  0B30 0000 0090 0040          IFETCH2-1 = MPCR                                           09990000 D
                                INDIRECT4:                                                   10000C00 D
0362  9809 0C40 9030 00F0          B R = A3                       % (Y)31-29                  10010000 D
0363  9010 0000 0000 00B0          ONE = LIT; 29 = SAR                                        10020C00 D
0364  9809 E158 000C C0F0          A3 GTR LIT                                                 10030C00 D
0365  7019 0000 0000 00F0          IF FALSE THEN SKIP             % SKIP FOR OPTIONAL INDIRECTION 10040C00 D
0366  0056 0000 0030 0040          INDIRECT6-1 = MPCR             % NORMAL OR CA              10050C00 D
0367  9809 1800 8000 00F0          8100 R = B                                                 10060000 D
0368  0000 00C0 0000 0090          ZERO=LIT; 6=SAR                                            1007000C D
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0369  9809 CC5C 2000 00F0          A2 OR B=A2                    %SET A2(23)                    1C08CC00 D
036A  3230 0000 0090 00C0          FETCHOPTO-1 = AMPCR                                          1C090000 D
036B  9809 E152 0C00 00F0          A3 EQL LIT                                                   10100C00 D
036C  6833 0000 0000 C0F0          IF TRUE THEN CALL ELSE SKIP                                  1C110C00 D
036D  981B 0000 0000 00F0          SKIP                                                         10120C00 D
036E  3280 0000 0090 C060          FETCHOPT1-1 = CPCR                                           1013CC00 D
                                INDIRECT5:                                                      1C140C00 D
036F  9809 E0C0 0090 00F0          A3 = MIR,LMAR; SET GC2                                       10150C00 D
0370  0180 0009 0030 00E0          YADDR=LIT                                                    1C160C00 D
0371  2300 0000 0090 0060          OUTPUT1-1 = CPCR              % SAVE Y AT 19                 10170C00 D
0372  0030 0000 0C90 0040          IFETCH2-1 = MPCR                                             10180C00 D
                                INDIRECT6:                                                      10190000 D
0373  9809 E000 9090 C0F0          A3 R = A3                     % A3=(Y)31-29                  1C200C00 D
0374  1000 0000 0000 0000          1 = SAR                                                      10210C00 D
0375  9809 E000 0000 00F0          A3                            % A3 = (Y)31,3C                 10220C00 D
0376  5808 00C0 0C90 00F0          IF LST THEN STEP ELSE SKIP                                   10230000 D
0377  0060 0000 0030 0040          INDIRECT8-1 = MPCR                                           10240C00 D
0378  9809 1800 8B00 00F0          B190 R = B                    % NORMAL INDIRECTION            1025CC00 D
0379  1000 0000 0000 0010          9=SAR                                                        1C260C00 D
037A  9809 CC5C 2090 C0F0          A2 OR B=A2                    %SET A2(22)                    10270C00 D
                                INDIRECT7:                                                      1C280000 D
037B  3120 00C0 0090 C060          FETNORM-1 = CPCR                                             10290C00 D
037C  9809 E000 0090 00F0          A3 = MIR                                                     1C300C00 D
037D  36E0 0000 0090 0040          INDIRECT5-1 = MPCR                                           10310C00 D
                                INDIRECT8:                                                      10320C00 D
037E  9809 A0C0 9090 C0F0          A1 R = A3                     % CHECK CA                     10330000 D
037F  2000 0000 0030 003C          26 = SAR                      % OPCODE                       10340000 D
0380  0D70 0000 C000 0060          CONDCHECK-1 = CPCR                                           1035CC00 D
0381  3819 0000 0090 00F0          IF LC2 THEN SKIP                                             10360C00 D
0382  0A50 0000 009C 0040          IFETCH-1 = MPCR                                              10370000 D
0383  9809 2001 0B90 00F0          LIT L=B                       %SET BITS 22,23                10380000 D
0384  2030 00C0 0090 0090          3=LIT; COMP 22=SAR                                           10390C00 D
0385  9809 CC5C 2090 C0F0          A2 OR B=A2                    %SET A2(22,23)                 10400C00 D
0386  37A0 0000 0090 0040          INDIRECT7-1 = MPCR                                           1041CC00 D
                                ANCMP0:                         %A1=A-REG REFERENCED           1042CC00 D
0387  2920 0000 0090 0060          COUNTONES-1=CPCR              %A3=ONES COUNT                 10430C00 D
0388  9809 A643 0090 00F0          A1+AMPCR=AMPCR                                               1C440000 D
0389  0080 0000 0000 C0C0          AOP-1=AMPCR                                                  10450C00 D
038A  9809 A0C0 C03C 00F0          A1=MAR                        %ADDRESS OF A-REG              1046CC00 D
038B  A824 0000 0090 08F0          MR1;EXEC;IF ROC               %READ A-REG;EXECUTE CODE HANDLER 1047CC00 D
038C  AC08 0000 0C0C C0F0          WHEN ROC THEN BEX             %B=(A)                         1048CC00 D
038D  4836 0C40 0090 00F0          B;CALL                        %EXECUTE CODE HANDLER          10490C00 D
038E  2CF0 00C0 0090 C040          GC2CHECK1-1=MPCR              %TERMINATE                     10500C00 D
038F  2E50 0000 0090 0040          RPTCHECK1-1=MPCR              %NO TERMINATE                  10510C00 D
                                %                                                               10520C00 D
                                $-CODE                                                          10530000 D
0390                            AOP:    AOP0-1=AMPCR. AOP1-1=AMPCR. AOP2-1=AMPCR. AOP3-1=AMPCR 10540C00 D
0394                                    AOP4-1=AMPCR. AOP5-1=AMPCR. AOP6-1=AMPCR. AOP7-1=AMPCR 10550C00 D
                                $POP CODE                                                       1C560C0C D
0398  9809 0C52 0000 C0F0       AOP0:   0 EQL B                                                 10570C00 D
0399  602F 0000 0000 00F0               IF FALSE THEN JUMP ELSE RETN                           10580C00 D
039A  9809 0C52 0000 00F0       AOP1:   0 EQL B                                                 10590C00 D
039B  602F 0000 0000 C0F0               IF TRUE THEN JUMP ELSE RETN                            1060CC00 D
039C  9839 0C52 000C 00F0       AOP2:   0 EQL B;IF MST THEN RETN                                1061CC00 D
039D  602F 0000 0090 00F0               IF TRUE THEN JUMP ELSE RETN                            10620C00 D
039E  9829 0C58 0000 00F0       AOP3:   0 GTR B;IF MST THEN JUMP                                1063CC0C D
039F  702F 0000 0090 00F0               IF TRUE THEN JUMP ELSE RETN                            10640C00 D
03A0  983F 0000 0000 00F0       AOP4:   RETN                                                    10650C00 D
03A1  9809 E000 0000 C0F0       AOP5:   A3.  IF NOT LST THEN JUMP ELSE RETN                     1066CC0C D
03A2  502F 0000 0090 00F0
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03A3  4809 E000 0030 00F0      AOP6:   A3.  IF LST THEN JUMP ELSE RETN                          10670000 D
03A4  582F 0000 0030 00F0
03A5  483F 0000 0000 00F0      AOP7:   RETN                                                    10680000 D
                               $                                                               10690000 D
                               ACMP0:   %CHECK CONDITION BITS FOR TERMINATING REPEAT           10700000 D
03A6  4809 A640 0040 00F0              A1+AMPCR=AMPCR              %A1=A-REG REFERENCED         10710000 D
03A7  0E10 0000 0000 00C0              ACO-1=AMPCR                                             10720000 D
03A8  0000 0000 0000 C030              COMP 1=SAR                                              10730000 D
03A9  4809 C001 9030 00F0              A2 C=A3                     %EQL IS LSB;GEQ IS MSB;LIMITS 2ND MSB10740000 D
03AA  4824 0000 0030 00F0              EXEC                                                    10750000 D
03AB  4836 E000 0030 00F0              A3;CALL                     %CALL CONDITION HANDLER     10760000 D
03AC  2CF0 0000 0030 C040              GC2CHECK1-1=MPCR            %TERMINATE                  10770000 D
03AD  2E50 00C0 0030 0040              RPTCHECK1-1=MPCR                                        10780000 D
                               $-CODE                                                          10790000 D
03AE                           ACO:    ACO0-1=AMPCR. ACO1-1=AMPCR. ACO2-1=AMPCR. ACO3-1=AMPCR 10800000 D
03B2                                   ACO4-1=AMPCR. ACO5-1=AMPCR. ACO6-1=AMPCR. ACO7-1=AMPCR 10810000 D
                               $POP CODE                                                       10820000 D
03B6  502F 0000 0030 00F0      ACO0:   IF NOT LST THEN JUMP ELSE RETN                          10830000 D
03B7  582F 0000 0000 00F0      ACO1:   IF LST THEN JUMP ELSE RETN                              10840000 D
03B8  540F E0C0 0030 00F0      ACO2:   IF NOT LST THEN A3;STEP ELSE RETN                       10850000 D
03B9  482F 00C0 0030 00F0              IF MST THEN JUMP ELSE RETN                              10860000 D
03BA  482F 0000 0000 00F0      ACO3:   IF MST THEN JUMP ELSE RETN                              10870000 D
03BB  402F 0000 0000 00F0      ACO4:   IF NOT MST THEN JUMP ELSE RETN                          10880000 D
03BC  540F E000 0030 00F0      ACO5:   IF NOT LST THEN A3;STEP ELSE RETN                       10890000 D
03BD  402F 0000 0030 00FC              IF NOT MST THEN JUMP ELSE RETN                          10900000 D
03BE  4809 E00A 0000 00F0      ACO6:   A3 0AD 0                    %TEST LIMITS BIT 2ND MSB    10910000 D
03BF  482F 0000 0030 00F0              IF MST THEN JUMP ELSE RETN                              10920000 D
03C0  4809 E00A 0000 00F0      ACO7:   A3 0AD 0                    %TEST LIMITS BIT 2ND MSB    10930000 D
03C1  402F 00C0 0030 00F0              IF NOT MST THEN JUMP ELSE RETN                          10940000 D
                               $                                                               10950000 D
                               CONDCHECK:                          %RETURN LC1=>REPEATABLE     10960000 D
03C2  4809 0641 0010 24F0              AMPCR L=BR2;ASE             %LC2 => CHAR.ADDRESSABLE    10970000 D
03C3  0000 0000 0000 003C              COMP 0=SAR                  %SAVE RETURN ADDRESS IN BR2 10980000 D
03C4  4809 E640 0040 00F0              A3+AMPCR=AMPCR              %RETURN SAVED IN BR2;       10990000 D
03C5  0EA0 0000 0000 00C0              CONDTABLE-1=AMPCR           %SET CONDITION CODE         11000000 D
03C6  2009 0C41 8030 00F0              B C=0;IF LC1                                            11010000 D
03C7  0000 00C0 0030 C020              20=SAR                                                  11020000 D
03C8  3024 0000 0030 00F0      SETUPCD:  EXEC;IF LC2                                           11030000 D
03C9  4809 2640 0040 C0F0              LIT+AMPCR=AMPCR             %SETUP TO EXECUTE CONDITIONS 11040000 D
03CA  0ED0 0000 0000 00C0              SETCOND-1=AMPCR                                         11050000 D
03CB  4809 2C40 0035 00F0              LIT NAN B=CTR               %SAVE SUBOPCODE IN CTR      11060000 D
03CC  0070 0000 0000 0090              7=LIT;0=SAR                                             11070000 D
03CD  482D 0000 0030 00F0              JUMP                        %EXECUTE SETCOND + VALUE IN TABLE 11080000 D
03CE  0EC0 0000 0000 00C0      SETCOND:  SPECCOND-1=AMPCR          %0=LIT=> 02 OR 03 OPCODE    11090000 D
03CF  49C9 0000 0000 00F0              SET LC1                     %1=LIT R OR CA.             11100000 D
03D0  4858 0000 0030 00F0              SET LC2;SKIP                %2=LIT NOR P BUT CA         11110000 D
03D1  49C9 0000 0000 00F0              SET LC1                     %3=LIT NOT CA BUT R         11120000 D
03D2  4809 0F40 8040 00F0      CONDEXIT: BMAR R=AMPCR              %4=LIT NOT CA & NOT R       11130000 D
03D3  4809 0000 0D30 00F0              BMI                         %RESET B                    11140000 D
03D4  482D 0000 0030 00F0              JUMP                        %RETURN TO CALLING ROUTINE  11150000 D
                               SPECCOND:                                                       11160000 D
03D5  4809 6640 0040 00F0              CTR+AMPCR=AMPCR             %MUST BE 02/03              11170000 D
03D6  0ED0 00C0 0030 00C0              SUBTABLE-1=AMPCR                                        11180000 D
03D7  4809 E152 0030 00F0              A3 EQL LIT                  %CHECK FOR 03               11190000 D
03D8  0030 0000 0000 00E0              3=LIT                                                   11200000 D
03D9  6C08 2640 0040 00FC              IF TRUE THEN LIT+AMPCR=AMPCR;STEP ELSE SKIP             11210000 D
03DA  0080 00C0 0030 00E0              8=LIT                       %OFFSET PAST 02 CODES       11220000 D
03DB  4809 0000 0030 00F0              STEP                                                    11230000 D
03DC  3C70 0000 0030 C040              SETUPCD-1=MPCR              %USE CODE FOR REGULAR OPCODES 11240000 D
                               $-CODE                                                          11250000 D
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                                    CONDTABLE: $4=NOT CA OR R;3=NOT CA/R;2=CA/NOT R;1=CA/R;0=C2 OR 03          11260C00 D
03DD                                        4=LIT. 3=LIT. 0=LIT. 0=LIT. 4=LIT. 4=LIT. 4=LIT. 4=LIT. 1=LIT   11270C00 D
03E6                                        2=LIT. 1=LIT. 1=LIT. 1=LIT. 1=LIT. 1=LIT. 1=LIT. 1=LIT. 1=LIT   11280000 D
03EF                                        1=LIT. 1=LIT. 1=LIT. 2=LIT. 1=LIT. 1=LIT. 4=LIT. 4=LIT. 3=LIT   11290000 D
03F8                                        3=LIT. 1=LIT. 1=LIT. 1=LIT. 1=LIT. 1=LIT. 1=LIT. 3=LIT. 1=LIT   11300C00 D
0401                                        1=LIT. 1=LIT. 1=LIT. 1=LIT. 4=LIT. 4=LIT. 4=LIT. 4=LIT. 3=LIT   11310C00 D
040A                                        3=LIT. 3=LIT. 3=LIT. 4=LIT. 4=LIT. 4=LIT. 4=LIT. 4=LIT. 4=LIT   1132CC00 D
0413                                        4=LIT. 4=LIT. 4=LIT.  4=LIT. 4=LIT. 4=LIT. 4=LIT. 4=LIT. 4=LIT   11330000 D
041C                                        4=LIT                                                            11340C00 D
                                    SUBTABLE:    $USED FOR OPCODES C2 & 03                                   1135CC00 D
041D                                          1=LIT. 4=LIT. 4=LIT. 4=LIT. 1=LIT. 1=LIT. 4=LIT. 4=LIT      11360C00 D
0425                                        3=LIT. 3=LIT. 1=LIT. 3=LIT. 1=LIT. 1=LIT. 1=LIT. 3=LIT          11370C00 D
                                    $POP CODE                                                                    11380C00 D
                                    $                                                                            11390C00 D
                                    $                                                                            11400000 D
                                    $ ********************          LOGIC OPERATORS       ******************   11410C00 D
                                    OPR01:                                                                       11420000 D
042D  1270 0008 0080 0060                   Y2FETCH-1=CPCR                                                   11430000 D
042E  246C 0008 0C00 0060                   GETF-1=CPCR                 $RETURNS F2-FIELD IN A3              11440C00 D
042F  4809 E640 0040 00F0                   A3+AMPCR=AMPCR                                                   11450C00 D
0430  0480 0008 0080 C0C0                   OPR01XX-1=AMPCR                                                  1146CC00 D
0431  4809 A008 9000 00F0                   A1 R=A3                     $(A)=>B                              1147CC00 D
0432  8070 0008 0090 00A0                   23=SAR;7=LIT                                                     11480C00 D
0433  4809 0F40 4000 00F0                   BMAR=A1                     $SAVE ADDRESS OF Y                   11490C00 D
0434  4809 E156 009C 00F0                   A3 AND LIT=MAR                                                   11500C00 D
0435  A824 0C40 1000 00F0                   B=A3;EXEC;MR1;IF RDC        $(Y)=>A3                             11510C00 D
0436  AC28 0008 0C00 00F0                   WHEN RDC THEN BEX;JUMP      $(A)=B;ADDR OF Y=A1;(Y)=A3           11520000 D
                                    $   ********************      OPCODE 02      **************************   11530C00 D
                                    OPR02:                                                                       11540C00 D
0437  127C 00C0 0030 0060                   Y2FETCH-1 = CPCR            $ Y VALUE => B                       11550C00 D
0438  4809 0F40 0030 00F0                   BMAR = MIR                  $ SAVE Y ADDR                        1156CC00 D
0439  246C 0008 0080 0060                   GETF-1=CPCR                 $RETURNS F2-FIELD IN A3              11570000 D
043A  4809 E640 0040 00F0                   A3 + AMPCR = AMPCR                                               11580C00 D
043B  0480 0008 0080 C0C0                   OPR02XX-1 = AMPCR                                                11590C00 C
043C  4809 A008 9000 00F0                   A1 R = A3                                                        11600C00 D
043D  8070 0008 0030 00A0                   23=SAR;7=LIT                                                     1161CC00 D
043E  4824 E156 009C 00F0                   A3 AND LIT = MAR; EXEC      $ A-REG                          11620C00 D
043F  A809 0008 0C00 00F0                   MR1; IF RDC                                                      11630C00 D
0440  AC28 0C40 1C00 00F0                   WHEN RDC THEN B=A3;BEX;JUMP    $ A(A)=>B,Y=> A3                  11640C00 D
                                    $ ************************        REPLACE LOGICALS       ***************   11650000 D
                                    OPR03:                                                                       11660C00 D
0441  2460 00C0 003C 0060                   GETF-1=CPCR                 $RETURNS F2-FIELD IN A3              11670C00 D
0442  007C 0008 0000 00E0                   7=LIT                                                            1168CC00 D
0443  4849 E152 003C 00F0                   A3 EOL LIT; SET LC2         $SIGNALS REPEAT INSTR.               11690000 D
0444  42C0 0008 0090 00C0                   OPR01-1=AMPCR                                                    11700C00 D
0445  67D9 E152 0C00 00F0                   IF FALSE THEN A3 EOL LIT;SET LC1;SKIP %F2=5=>SAME AS 3&R01X7     11710C00 D
0446  0EE0 0003 0000 0040                   OPR03X7-1=MPCR                                                   1172CC00 D
0447  0050 0008 0C30 C0E0                   5=LIT                                                            11730C00 D
0448  6C0D 2001 0B30 00F0                   IF TRUE THEN LIT L=B;STEP ELSE JUMP                              11740C00 D
0449  007C 00C0 0090 0090                   7=LIT;COMP 20=SAR           $SUBSTITUTE 7 IN F2 FIELD            11750C00 D
044A  482D AC5C 4030 00F0                   A1 OR B=A1;JUMP                                                  11760C00 D
                                    $ ************************    DOUBLE WORD OPERATIONS       ************11770C00 D
                                    OPR05:                                                                       1178CC00 D
044B  1270 0003 0030 0060                   Y2FETCH-1=CPCR              $MAR2=Y-ADDR;A3,MIR=(Y)              11790C00 D
044C  246C 0008 0090 0060                   GETF-1=CPCR                 $RETURNS F2-FIELD IN A3              11800C00 D
044D  4809 E640 0040 00F0                   A3+AMPCR=AMPCR                                                   1181C000 D
044E  0500 0008 0C0C 00C0                   OPR05XX-1=AMPCR                                                  11820C00 D
044F  4809 A0C0 9000 00F0                   A1 R=A3                     $ISOLATE A-FIELD                     11830C00 D
0450  8070 0008 0F30 00A0                   7=LIT;23=SAR                                                     11840C00 D
0451  4824 E156 1000 00F0                   A3 AND LIT=A3;EXEC          $A3=A-FIELD                          11850C00 D
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0452  902D 0C40 0090 00F0          0=MIR;JUMP                  $MAR2=Y-ADDR;MIR=(Y)                  11860C00 D
                                $ ************************   FLOATING POINT SUBROUTINES   ************11870C00 D
                                0PR06:                                                               11880C00 D
0453  224C 0000 0090 0040          UNWRITTEN-1=MPCR            $PRINT ERROR AND RETURN TO IFETCH     11890C00 D
                                $************************    EXTERNAL FUNCTION      ***************** 11900C00 D
                                0PR07:                                                               11910C00 D
0454  127C 0000 009C C06C          Y?FETCH-1=CPCR                                                     11920C00 D
0455  9009 0F40 0B90 00F0          0MAR=B                      $B=ADDRESS OF Y+(B)+(S)                11930C00 D
0456  2460 0000 0090 0060          GETF-1=CPCR                 $RETURNS F2-FIELD IN A3                11940C00 D
0457  9009 E640 0040 C0F0          A3+AMPCR=AMPCR                                                     11950C00 D
0458  0600 0000 0090 00C0          0PR07XX-1=AMPCR             $SETUPT FOR JUM                        11960C00 D
0459  9009 A0C0 9000 00F0          A1 R=A3                     $ISOLATE A FIELD                       11970C00 D
045A  8070 0003 009C 00A0          7=LIT;23=SAR                                                       11980C00 D
045B  9024 E156 1090 00F0          A3 AND LIT=A3;EXEC                                                 11990C00 D
045C  902D 0000 009C 00F0          JUMP                                                               12000C00 D
                                $ ************************     LOAD A     ************************** 12010C00 D
                                0PR10:                          $ LA                                 12020C00 D
045D  0CF0 0000 0090 0060          YFETCH-1 = CPCR              $PUTS PROPER INFO INTO MIR             12030C00 D
045E  24C0 00C0 0000 0060          GETAA3-1=CPCR                $RETURNS A-FIELD IN A3&MAR             12040C00 D
045F  22F0 0000 0000 C04C          OUTPUT-1=MPCR                                                      12050C00 D
                                $ ************************     LOAD A AND INDEX B     ***************** 12060C00 D
                                0PR11:                          $ LXB                                12070C00 D
0460  0CF0 0000 0000 0060          YFETCH-1 = CPCR              $ PUTS INFO INTO MIR                   12080C00 D
0461  24C0 0003 0030 0060          GETAA3-1=CPCR                $RETURNS A-FIELD IN A3&MAR             12090C00 D
0462  9009 A000 9000 18F0          A1 R = A3;MM1;IF SAI         $ WRITE A-REG                          12100C00 D
0463  1070 0000 0090 00A0          17 = SAR; 7 = LIT                                                  12110C00 D
0464  9009 E156 1000 00F0          A3 AND LIT = A3              $ B-FIELD = A3                         12120C00 D
0465  9C08 E140 003C C0F0          WHEN SAI THEN A3+LIT=MAR                                           12130000 D
0466  0000 0003 0000 00A0          0BASE = LIT; 16 = SAR                                              12140C00 D
0467  A009 0000 0090 00F0          MR1; IF RDC                                                        12150C00 D
0468  AC08 0003 0C30 C0F0          WHEN RDC THEN BEX                                                  12160C00 D
0469  01BC 0000 0000 00E0          YADDR=LIT                                                          12170000 D
046A  9009 0C46 0090 00F0          0 + B + 1 = MIR                                                    12180C00 D
046B  22F0 0000 0090 0040          OUTPUT-1=MPCR                                                      12190C00 D
                                $ ************************     LOAD DIFFERENCE     ****************** 12200C00 D
                                0PR12:                          .$LDIF                               12210C00 D
046C  0CFC 0000 0090 0060          YFETCH-1 = CPCR                                                    12220C00 D
046D  24C0 00C0 0000 C060          GETAA3-1=CPCR                $RETURNS A-FIELD IN A3&MAR             12230000 D
046E  A009 0000 0090 00F0          MR1; IF RDC                                                        12240C00 D
046F  AC08 E0C0 0C3C 00F0          WHEN RDC THEN A3 +1 = MAR,BEX    $ MAR = A+1 REG                   12250C00 D
0470  9009 0C40 1090 00F0          B = A3,BMI                                                         12260C00 D
0471  9009 E0C0 0C30 00F0          A3 = MIR                                                           12270C00 D
0472  9009 0C40 1D0C 00F0          B = A3,BMI                                                         12280C00 D
0473  9009 EC5E 1000 00F0          A3 - B = A3,MIR                                                    1229CC00 D
0474  7409 E0DE 1000 00F0          IF NOT A0V THEN A3-1=A3,MIR                                        12300C00 D
0475  2019 0000 0090 C0F0          IF NOT LC1 THEN SKIP                                               12310000 D
0476  0EF0 0000 0000 0040          0PR36X1 -1 = MPCR                                                  12320C00 D
0477  22F0 0000 0090 0040          OUTPUT-1=MPCR                                                      12330C00 D
                                $ ************************     SUBTRACT A     ********************** 12340C00 D
                                0PR13:                          $ AMA                                12350C00 D
0478  0CF0 0000 0090 C060          YFETCH-1 = CPCR                                                    12360000 D
0479  24C0 0000 0000 0060          GETAA3-1=CPCR                $RETURNS A-FIELD IN A3&MAR             12370C00 D
047A  A009 0000 0090 00F0          MR1; IF RDC                                                        12380C00 D
047B  AC08 0000 0C30 00F0          WHEN RDC THEN BEX                                                  1239CC00 D
047C  9009 0C40 1090 C0F0          B = A3,BMI                                                         12400000 D
047D  9009 EC5E 1090 C0F0          A3 - B = A3,MIR                                                    12410C00 D
047E  7409 E0DE 1090 00F0          IF NOT A0V THEN A3-1=A3,MIR                                        1242CC00 D
047F  22F0 0000 0090 0040          OUTPUT-1=MPCR                                                      12430C00 D
                                $ ************************     ADD A     ************************** 12440C00 D
                                0PR14:                          $ AA                                 12450000 D
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0480  0CF0 0000 0000 C060          YFETCH-1 = CPCR                                  12460C00 D
0481  2490 0000 0000 0060          GETAB-1=CPCR              %RETURNS A-FIELD IN B&MAR  12470C00 D
0482  A809 0000 0000 00F0          MR1; IF RDC                                      12480000 D
0483  AC00 0000 0C90 00F0          WHEN RDC THEN BEX                                12490C00 D
0484  9809 EC40 0090 00F0          A3 + B = MIR                                     12500C00 D
0485  7C09 EC46 0090 00F0          IF AOV THEN A3+B+1=MIR                           12510000 D
0486  6C09 00C0 0090 00F0          IF ABT THEN 0=MIR         %ELIMINATE NEGATIVE 0  12520C00 D
0487  22F0 0000 0090 C040          OUTPUT-1=MPCR                                    12530C00 D
% ********************     LOAD SUM     ************************                  12540000 D
OPR15:                             % LSUM                                         12550000 D
0488  0CF0 0000 0090 0060          YFETCH-1 = CPCR                                  12560C00 D
0489  24C0 0000 0090 0060          GETAA3-1=CPCR             %RETURNS A-FIELD IN A3&MAR 12570C00 D
048A  A809 00C0 0090 00F0          MR1; IF RDC                                      12580C00 D
048B  AC00 E0C0 1C90 C0F0          WHEN RDC THEN A3+1=A3,BEX %ADDRESS A+1 REGISTER  12590C00 D
048C  9809 E156 009C 00F0          A3 AND LIT=MAR            %A(B)=A(0)             12600C00 D
048D  0070 0000 0090 00E0          7=LIT                                            12610000 D
048E  9809 0C40 1D90 00F0          B = A3,BMI                                       12620C00 D
048F  9809 EC40 0090 00F0          A3 + B = MIR                                     12630C00 D
0490  7C09 EC46 0090 00F0          IF AOV THEN A3+B+1=MIR                           12640C00 D
0491  6C09 0000 0090 C0F0          IF ABT THEN 0=MIR         %ELIMINATE NEGATIVE 0  12650000 D
0492  22F0 0000 0090 C040          OUTPUT-1=MPCR                                    12660C00 D
% ********************     LOAD NEGATIVE     ********************                 12670C00 D
OPR16:                             % LNA                                          12680C00 D
0493  0CF0 0000 0090 0060          YFETCH-1 = CPCR                                  12690C00 D
0494  2490 0000 0090 0060          GETAB-1=CPCR              %RETURNS A-FIELD IN B&MAR  12700000 D
0495  9809 E0C2 0090 00F0          NOT A3 = MIR                                     12710C00 D
0496  22F0 0000 009C C040          OUTPUT-1=MPCR                                    12720000 D
% ********************     LOAD MAGNITUDE     ********************               12730C00 D
OPR17:                             % LM                                           12740000 D
0497  0CF0 0000 0090 0060          YFETCH-1=CPCR                                    12750C00 D
0498  2490 0000 0090 0060          GETAB-1=CPCR              %RETURNS A-FIELD IN B&MAR  12760C00 D
0499  9809 E0C0 0C90 00F0          A3                                               12770C00 D
049A  9C09 E0C2 0C90 C0F0          IF MST THEN NOT A3 = MIR                         12780C00 D
049B  22F0 0000 0090 C040          OUTPUT-1=MPCR                                    12790C00 D
% ********************     LOAD B     ************************                    12800C00 D
OPR20:                             % LB                                           12810000 D
049C  0CF0 0000 0090 0060          YFETCH-1 = CPCR                                  12820C00 D
049D  24C0 0000 0090 0060          GETAA3-1=CPCR             %RETURNS A-FIELD IN A3&MAR 12830C00 D
049E  9809 E0C2 0000 00F0          NOT A3                                           12840C00 D
049F  0A50 0000 0090 00C0          1FETCH-1=AMPCR                                   12850C00 D
04A0  6829 0000 0090 00F0          IF ABT THEN JUMP          % ABT,A-FIELD = 0      12860000 D
04A1  9809 E140 009C 00F0          A3 + LIT = MAR                                   12870C00 D
04A2  0000 0000 0C90 00E0          BBASE = LIT                                      12880C00 D
04A3  22F0 0000 0090 0040          OUTPUT-1=MPCR                                    12890000 D
% ********************     ADD B     ************************                    12900C00 D
OPR21:                             % AB                                           12910000 D
04A4  0CF0 0000 0090 C060          YFETCH-1 = CPCR                                  12920C00 D
04A5  24C0 00C0 0090 0060          GETAA3-1=CPCR             %RETURNS A-FIELD IN A3&MAR 12930C00 D
04A6  9809 E0C2 0000 00F0          NOT A3                                           12940C00 D
04A7  0A50 0000 0090 C0C0          1FETCH-1=AMPCR                                   12950C00 D
04A8  6829 0000 0090 00F0          IF ABT THEN JUMP          % ABT, A-FIELD = 0     12960C00 D
04A9  9809 E140 0D9C 00F0          A3 + LIT = MAR,BMI                               12970C00 D
04AA  000C 0000 0090 C0A0          BBASE = LIT; 16 = SAR                            12980C00 D
04AB  A809 0000 0000 00F0          MR1; IF RDC                                      12990C00 D
04AC  AC00 0C40 1C90 00F0          WHEN RDC THEN B = A3,BEX                         13000C00 D
04AD  9809 EC40 0090 00F0          A3+B=MIR                  %(Y)+B(A)=>B(A)        13010000 D
04AE  7C09 EC46 0090 C0F0          IF AOV THEN A3+B+1=MIR                           13020C00 D
04AF  6C09 0000 C090 00F0          IF ABT THEN 0=MIR         %ELIMINATE NEGATIVE 0  13030C00 D
04B0  22F0 0000 0090 0040          OUTPUT-1=MPCR                                    13040000 D
% ********************     SUBTRACT B     ********************                   13050C00 D
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                        OPR22:                          % ANB                                   13060C00 D
04B1  0CF0 0000 0090 0060               YFETCH-1 = CPCR                                         13070C00 D
04B2  24C0 0000 0000 0060               GETAA3-1=CPCR           %RETURNS A-FIELD IN A3&MAR      13080C00 D
04B3  9009 E002 0090 00F0               NOT A3                                                  13090C00 D
04B4  0A50 0000 0090 00CC               IFETCH-1=AMPCR                                          13100C00 D
04B5  6029 0000 0090 00F0               IF ABT THEN JUMP        %A- FIELD = 0,ABT               13110000 D
04B6  9009 E140 003C 00F0               A3 + LIT = MAR                                          13120C00 D
04B7  0080 0000 0000 00A0               OBASE = LIT; 16 = SAR                                   13130C00 D
04B8  A009 0000 0090 00F0               MR1; IF RDC                                             13140C00 D
04B9  AC08 0000 0C90 C0F0               WHEN RDC THEN BEX       % READ B(A)                     13150C00 D
04BA  9009 0C40 1D30 C0F0               B=A3,BMI                                                13160C00 D
04BB  9009 EC5E 0090 00F0               A3-B=MIR                                                13170C00 D
04BC  7409 EC58 0090 C0F0               IF NOT AOV THEN A3-B-1=MIR                              13180C00 D
04BD  22FC 0000 0C00 0040               OUTPUT-1=MPCR                                           13190C00 D
                        %  ********************     STORE B     ********************            13200C00 D
                        OPR23:                          % SB                                    13210C00 D
04BE  9009 E800 0090 00F0               A3 = MIR                                                13220C00 D
04BF  24C0 0000 0000 0060               GETAB-1=CPCR            %RETURNS A-FIELD IN B&MAR       13230C00 D
04C0  9009 0C42 0090 00F0               NOT B                                                   13240C00 D
04C1  6C08 0000 0090 00F0               IF ABT THEN 0000 = MIR ELSE SKIP                        13250C00 D
04C2  0F0C 0000 003C 0040               AZERO-1 = MPCR                                          13260000 D
04C3  9009 2C48 0C3C C0F0               LIT + B = MAR                                           13270000 D
04C4  008C 0000 0090 00A0               OBASE=LIT;16=SAR                                        13280C00 D
04C5  A009 0000 009C 00F0               MR1; IF RDC                                             13290000 D
04C6  AC08 0000 0C90 C0F0               WHEN RDC THEN BEX                                       13300000 D
04C7  9009 0C41 0B30 00F0               B L = B                                                 13310C00 D
04C8  9009 0C48 B030 00F0               B R = MIR               % B(A) 15-0 = MIR               13320C00 D
04C9  4009 E000 000C C0F0       AZERO:  A3 = MAR                                                13330C00 D
04CA  1550 0000 0C0C C040               YSTORE-1 = MPCR                                         13340C00 D
                        %  ********************     STORE  A      ****************************  13350C00 D
                        OPR24:                          % SA                                    13360C00 D
04CB  2490 0000 0C90 C060               GETAB-1=CPCR            %RETURNS A-FIELD IN B&MAR       13370C00 D
04CC  A009 00C0 0090 00F0               MR1; IF RDC             % READ A(A)                     13380000 D
04CD  AC08 0000 0C30 C0F0               WHEN RDC THEN BEX                                       13390C00 D
04CE  4009 0C40 0030 C0F0               B = MIR                 % STORE A(A)                    13400C00 D
04CF  1550 0000 0030 0040               YSTORE - 1 = MPCR                                       13410C00 D
                        %  ********************     STORE A AND INDEX B     ****************** 13420C00 D
                        OPR25:                          % SXB                                   13430C00 D
04D0  A009 0000 0090 C0F0               MR1; IF RDC                                             13440C00 D
04D1  AC08 0000 0C00 C0F0               WHEN RDC THEN BEX                                       13450000 D
04D2  9009 0C46 0030 C0F0               B+1=MIR                 %INCREMENT B(B)                 13460C00 D
04D3  3120 0000 0030 0060               FETNORM-1 = CPCR        % A3,MAR2 = Y ADDR              13470C00 D
04D4  9009 A0C0 0BDC 00F0               A1 R = B                                                13480C00 D
04D5  1070 0000 0000 00AC               7 = LIT; 17 = SAR                                       13490C00 D
04D6  9009 2C56 0B00 C0F0               LIT AND B = B                                           13500000 C
04D7  9009 2C48 009C 00F0               LIT + B = MAR           % ADDR B(B)=>MAR                13510C00 D
04D8  0000 0000 0030 00EC               OBASE = LIT                                             13520C00 D
04D9  9009 A0C0 0B00 18F0               A1 R = B; MW1; IF SAI   % INC B(B)                      13530C00 D
04DA  B070 00C0 00B0 C0A0               23 = SAR; 7 = LIT                                       13540C00 D
04DB  9C08 2C56 000C 00F0               WHEN SAI THEN LIT AND B = MAR   % A-REG                 13550C00 D
04DC  A009 E003 0090 00FC               A3 = MIR; MR1; IF RDC   % Y ADDR=> MIR                  13560000 D
04DD  AC08 A0B0 9C0C 00F0               WHEN RDC THEN A1 R = A3,BEX   % A(A)=>B                 13570C00 D
04DE  0000 00C0 0030 0020               20 = SAR                                                13580C00 D
04DF  9009 E156 1C30 00F0               A3 AND LIT = A3                                         13590C00 D
04E0  9009 0C40 0D30 00FC               B = MIR, BMI            % Y ADDR=>B, A(A)=>MIR           13600C00 D
04E1  9009 E64B 0090 00F0               A3 + AMPCR = AMPCR                                      13610C00 D
04E2  1060 00C0 0030 00C0               KSTABLE-1 = AMPCR                                       13620C00 D
04E3  9009 0C43 001C 00F0               B = MAR2                                                13630C00 D
04E4  A024 00C0 0030 0CF0               EXEC; MR2; IF RDC                                       13640C00 D
04E5  902D 0D0D 0000 00FC               JUMP                                                    13650C00 D
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                                $  ********************      STORE NEGATIVE      ********************  13660000 D
                                OPR26:                          $ SNA                               13670000 D
04E6  2490 0000 0000 0060               GETAB-1=CPCR            $RETURNS A-FIELD IN B&MAR           13680000 D
04E7  A009 0000 0000 00F0               MR1; IF RDC                                                 13690000 D
04E8  AC08 0000 0C0C C0F0               WHEN RDC THEN BEX       $ B => A(A)                         13700000 D
04E9  9009 0C42 0030 C0F0               NOT B = MIR             $ ONE'S COMP                        13710000 D
04EA  1550 00C0 0C00 0040               YSTORE-1 = MPCR                                             13720000 D
                                $  ********************     STORE MAGNITUDE     ********************  13730000 D
                                OPR27:                          $ SM                                13740000 D
04EB  2490 0000 0030 0060               GETAB-1=CPCR            $RETURNS A-FIELD IN B&MAR           13750000 D
04EC  A009 0000 0000 C0F0               MR1; IF RDC                                                 13760000 D
04ED  AC08 0000 0C30 00F0               WHEN RDC THEN BEX       $ A(A)=> B                          13770000 D
04EE  9009 0C40 0030 00F0               B = MIR                                                     13780000 D
04EF  9C09 0C42 0030 C0F0               IF MST THEN NOT B = MIR $ COMP B IF BIT 31 = 1               13790000 D
04F0  9009 E000 003C 00F0               A3 = MAR                $ RESTORE TO READ B(B)              13800000 D
04F1  1550 0000 0000 0040               YSTORE-1 = MPCR                                             13810000 D
                                $  ********************      CLEAR BIT      ********************  13820000 D
                                OPR32:                          $ BZ                                13830000 D
                                $     TAKE THE NUMBER IN AK FIELD, CLEAR THAT BIT IN Y                13840000 D
04F2  1270 00C0 0000 0060               Y2FETCH-1=CPCR          $GET Y-ADDRESS AND IGNORE K         13850000 D
04F3  9009 ABC1 1030 C0F0               A1 L=A3                 $ISOLATE A-FIELD                    13860000 D
04F4  2000 00C0 0030 0030               COMP 6=SAR                                                  13870000 D
04F5  9009 E0C0 9C30 00F0               A3 R=A3                                                     13880000 D
04F6  2000 0000 0000 0030               26=SAR                                                      13890000 D
04F7  9009 E000 0030 00F0               A3=SAR                  $SAR=AK-FIELD                       13900000 D
04F8  9009 0C41 9030 40F0               B C=A3,CSAR             $BIT(AK) IN LSB                     13910000 D
04F9  2C19 E0DD 0000 C0F0               IF LC1 THEN A3 OR B001 C=MIR;SKIP                           13920000 D
04FA  9009 E0CF 0000 00F0               A3 AND B110 C=MIR       $CLEAR BIT IF OPR32 ELSE SET        13930000 D
04FB  2370 00C0 0000 0040               YOUT-1=MPCR                                                 13940000 D
                                $  ********************       SET BIT       ********************  13950000 D
                                OPR33:                          $ BS                                13960000 D
                                $     SAME CODE AS OPCODE 32 SO WILL USE THAT EXCEPT SET THE BIT   13970000 D
04FC  49C9 0000 0030 00F0               SET LC1                                                     13980000 D
04FD  4F10 0000 0000 0040               OPR32-1 = MPCR                                              13990000 D
                                $  ********************      REPLACE ADD      ********************  14000000 D
                                OPR34:                          $ RA                                14010000 D
04FE  0CF0 0000 0030 C060               YFETCH-1 = CPCR         $ Y VALUE => A3,MIR                 14020000 D
04FF  24C0 00C0 0000 0060               GETAA3-1=CPCR           $RETURNS A-FIELD IN A3&MAR          14030000 D
0500  A009 E0C0 1000 00F0               A3 + 1 = A3;MR1; IF RDC                                     14040000 D
0501  AC08 E156 0C0C C0F0               WHEN RDC THEN A3 AND LIT=MAR,BEX                            14050000 D
0502  9049 0C40 1030 00F0               B=A3,BMI;SET LC2        $A(A)=>A3,Y=>B;SIGNAL REPEAT        14060000 D
0503  9009 EC40 1030 00F0               A3 + B = A3,MIR                                             14070000 D
0504  7C09 E0C0 1030 00F0               IF AOV THEN A3+1=A3,MIR                                     14080000 D
0505  6C09 0000 1030 C0F0               IF ABT THEN 0=A3,MIR                                        14090000 D
0506  2300 0000 0030 0060               OUTPUT1-1 = CPCR        $ A(A)+Y=>A(A+1)                    14100000 D
0507  1550 0000 0000 0040               YSTORE - 1 = MPCR                                           14110000 C
                                $  ********************     REPLACE INCREMENT     ********************  14120000 D
                                OPR35:                          $ RI                                14130000 D
0508  0CF0 0000 0000 0060               YFETCH-1 = CPCR         $ Y VALUE => A3,MIR                 14140000 D
0509  4049 E0C0 0030 00F0               A3+1=MIR;SET LC2        $(Y)+1=>MIR;SIGNAL REPEAT           14150000 C
050A  7C09 E0C6 0C30 00F0               IF AOV THEN A3+1+1=MIR                                      14160000 D
050B  6C09 0000 0030 00F0               IF ABT THEN 0=MIR       $ELIMINATE NEGATIVE 0               14170000 D
050C  2490 0000 0000 0060               GETAB-1=CPCR            $RETURNS A-FIELD IN B&MAR           14180000 D
050D  2300 0000 0C30 0060               OUTPUT1-1 = CPCR        $ Y+1 => A(A)                       14190000 D
050E  1550 0000 0000 0040               YSTORE-1=MPCR                                               14200000 D
                                $  ********************     REPLACE SUBTRACT      ********************  14210000 D
                                OPR36:                          $ RAN                               14220000 D
050F  49C9 0000 0030 C0F0               SET LC1                                                     14230000 D
0510  46BC 0000 0030 0040               OPR12 - 1 = MPCR        $ SAME CODE THRU HERE               14240000 D
0511  2300 C000 0000 006C       OPR36X1:  OUTPUT1-1 = CPCR                                          14250000 D
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0512  9849 0000 0000 00F0          SET LC2                    $SIGNALS REPEAT                    14260C00 D
0513  1550 0000 0000 C040          YSTORE - 1 = MPCR                                             14270C00 D
                                $  ################     REPLACE DECREMENT     ##################  14280C00 D
                                OPR37:                     $ RD                                 14290C00 D
0514  0CF0 0000 0030 C060          YFETCH-1=CPCR                                                 14300C00 D
0515  2490 0000 0030 C060          GETAB-1=CPCR               $RETURNS A-FIELD IN B&MAR          14310C00 D
0516  9809 E0DE 0030 00F0          A3-1=MIR                                                      14320C00 D
0517  7409 E0D8 0030 00F0          IF NOT AOV THEN A3-1-1=MIR                                    14330C00 D
0518  230C 0000 0030 0060          OUTPUT1 - 1 = CPCR         $ A(A)-1 => A(A)                   14340C00 D
0519  1550 00C0 0000 0040          YSTORE - 1 = MPCR                                             14350C00 D
                                $ ####################   MULTIPLY A(A)XY = A(A+1),A(A)          14360C00 D
                                OPR40:     $A3=(Y)=MULTIPLIER                                   14370C00 D
051A  0CF0 0000 0000 C060          YFETCH-1=CPCR              $A3=(Y)                            14380C00 D
051B  2270 0000 0030 0060          PUTPAR-1=CPCR              $SAVE A2                           14390C00 D
051C  2490 0000 0000 0060          GETAB-1=CPCR               $B,MAR=A-FIELD                     14400C00 D
051D  A809 E0C0 2030 00F0          A3=A2;MR1;IF RDC           $A2=(Y)                            14410C00 D
051E  AC08 0000 0C30 C0F0          WHEN RDC THEN BEX          $B=(A(A))                          14420C00 D
051F  2980 0000 0030 0060          MULTIPLY-1=CPCR            $A1=MOST;A3=LEAST                  14430C00 D
0520  9809 E0C0 0C30 00F0          A3=MIR                     $OUTPUT LEAST                      14440C00 D
0521  9809 0000 0000 18F0          MW1;IF SAI                                                    14450C00 D
0522  9C08 0F46 0C0C 00F0          WHEN SAI THEN BMAR+1=MAR                                      14460C00 D
0523  9809 A0C0 0030 00F0          A1=MIR                     $OUTPUT MOST                       14470C00 D
0524  9809 0000 0030 18F0          MW1;IF SAI                                                    14480C00 D
0525  9C08 0000 0030 00F0          WHEN SAI THEN 0;STEP                                          14490C00 D
0526  0A50 00C0 0030 00C0          IFETCH-1=AMPCR                                                14500C00 D
0527  22AC 0000 0C30 0040          GETPAR-1=MPCR              $RESTORE A2;RETURN TO IFETCH       14510C00 D
                                $ ####################   DIVIDE A(A+1) & A(A) / Y=>A(A+1) + A(A)  14520C00 D
                                OPR41:  $DIVIDE A1 & A3 / B =A1(QUOTIENT) + A3(REMAINDER       14530C00 D
0528  0CF0 0000 0030 0060          YFETCH-1=CPCR              $MIR=DIVISOR                       14540C00 D
0529  2270 0000 0030 C060          PUTPAR-1=CPCR              $SAVE A2                           14550C00 D
052A  9809 E0C0 0030 00F0          A3=MIR                     $MIT=DIVISOR=(Y)                   14560C00 D
052B  24C0 0000 0000 0060          GETAA3-1=CPCR                                                 14570C00 D
052C  9809 E0C0 000C 00F0          A3+1=MAR                   $A3=A ADDRESS                      14580C00 D
052D  9809 2F56 0C0C 00F0          LIT AND BMAR=MAR           $CONVERT A(8) TO A(0)              14590C00 D
052E  A809 0000 0030 08F0          MR1;IF RDC                 $READ A+1                          14600C00 D
052F  AC08 E0D0 0C0C 00F0          WHEN RDC THEN A3=MAR,BEX   $MAR SETUP FOR LEAST DIVIDEND      14610C00 D
0530  9809 0C40 1D90 00F0          B=A3,BMI                   $A3=DIVIDEND;B=DIVISOR             14620C00 D
0531  2A80 0000 0030 0060          DIVIDE-1=CPCR              $RETURNS A2=QUOTIENT;A1=REMAINDER  14630C00 D
0532  9809 C0C0 0090 00F0          A2=MIR                     $SETUP TO OUTPUT QUOTIENT          14640C00 D
0533  6C09 0000 0030 00F0          IF ABT THEN 0=MIR                                             14650C00 D
0534  9809 0000 0030 18F0          MW1;IF SAI                 $OUTPUT QUOTIENT                   14660C00 D
0535  9C08 0F46 000C 00F0          WHEN SAI THEN BMAR+1=MAR                                      14670C00 D
0536  9809 2F56 003C 00F0          LIT AND BMAR=MAR           $CONVERT A(8) TO A(0)              14680C00 D
0537  0070 0000 0000 00E0          7=LIT                                                         14690C00 D
0538  9809 A0D0 0C30 00F0          A1=MIR                     $OUTPUT REMAINDER                  14700C00 D
0539  6C09 A002 0030 00F0          IF ABT THEN NOT A1=MIR                                        14710C00 D
053A  9809 0000 0030 18F0          MW1;IF SAI                                                    14720C00 D
053B  9C08 0000 0000 00F0          WHEN SAI THEN 0;STEP                                          14730C00 D
053C  22A0 0000 0030 0060          GETPAR-1=CPCR              $RESTORE A2                        14740C00 D
053D  9809 C001 A090 40F0          A2 C=A2,CSAR                                                  14750C00 D
053E  9000 0000 0030 0030          COMP 3=SAR                                                    14760C00 D
053F  2C19 D01D A090 00F0          IF LC1 THEN A2 OR B100 C=A2;SKIP                              14770C00 D
0540  9809 D00F A090 00F0          A2 AND B011 C=A2                                              14780C00 D
0541  0A50 00C0 0000 0040          IFETCH-1=MPCR                                                 14790C00 D
                                $ ####################    COMPARE BIT TO ZERO       ##########  14800C00 D
                                OPR42:                     $BC                                  14810C00 D
0542  1270 0000 0C00 0060          Y2FETCH-1=CPCR             $GET (Y) INTO B                    14820C00 D
0543  9809 0C40 1C00 00F0          B=A3                       $CHECK BIT IN A3=(Y)               14830C00 D
0544  9809 A0C0 0B90 C0F0          A1 R=B                                                        14840C00 D
0545  03F0 0000 0030 00A0          63=LIT;20=SAR                                                 14850C00 D
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0546  4809 2C56 0000 00F0          LIT AND B=SAR              %AK FIELD IS SHIFT AMOUNT              14860C00 D
0547  4809 E0C0 9000 C0F0          A3 R=A3                    %BIT TO COMPARE IS LS                  14870C00 D
0548  4849 E000 0000 00F0          A3;SET LC2                 %CHECK LSB; SIGNAL REPEAT WITH LC2     14880C00 D
0549  5C19 D0CE 200C 00F0          IF LST THEN A2 AND B011 = A2;SKIP                                 14890C00 D
054A  4809 D01C 2030 00F0          A2 OR B100=A2              %SET EQUAL CONDITION BIT IN ASR        14900C00 D
054B  0A50 0000 0C0C C040          IFETCH-1=MPCR                                                     14910C00 D
                                 % ************************     COMPARE INDEX INCREMENT      **********  14920C00 D
                                 OPR43:                       %CXI                                   14930C00 D
054C  0CFC 0000 0000 0060          YFETCH-1=CPCR              %Y VALUE =A3,MIR                       14940C00 D
054D  2490 0000 0000 0060          GETAB-1=CPCR               %RETURNS A-FIELD IN B&MAR              14950C00 D
054E  4809 0C52 0000 00F0          0 EQL B                    %TEST FOR B(0) => NOOP IF TRUE         14960C00 D
054F  6019 0000 0000 00FC          IF FALSE THEN SKIP                                                14970C00 D
0550  0A50 0000 0000 0040          IFETCH-1=MPCR                                                     14980C00 D
0551  4809 2C40 003C 00F0          LIT+B=MAR                  %B(A) ADDRESS                          14990C00 D
0552  0000 0000 0000 00A0          BBASE=LIT;16=SAR                                                  15000C00 D
0553  A809 C001 AC00 00F0          A2 C=A2;MR1;IF RDC         %GET LIMITS BIT TO MSB                 15010C00 D
0554  A000 0000 0030 0030          COMP 2=SAR                                                        15020C00 D
0555  AC08 00C0 0CD0 00F0          WHEN RDC THEN BEX          %READ B(A)                             15030C00 D
0556  4809 0C40 1D00 40F0          B=A3,BMI,CSAR              %A3=B(A);B=(A)                         15040C00 D
0557  4809 E0C0 0030 C0F0          A3+1=MIR                   %INCREMENT B(A) THEN TEST B(A)>A(A)    15050C00 D
0558  4849 EC4C 0000 00F0          A3 XOR B;SET LC2           %TEST FOR UNLIKE SIGNS;SIGNAL REPEAT   15060C00 D
0559  480B EC5E 0000 00F0          A3 GEQ B; IF MST THEN STEP ELSE SKIP                              15070C00 D
055A  7708 00C0 0030 00F0          SKIP; IF FALSE THEN 0=MIR;SET LC1  %SET B(A)=0                    15080C00 D
055B  7FC9 00C0 0030 00F0          IF TRUE THEN 0=MIR;SET LC1 %SET B(A) = 0                          15090C00 D
055C  2C19 D01D A000 00F0          IF LC1 THEN A2 OR B100 C=A2;SKIP  %SET OUT OF LIMITS              15100C00 D
055D  4809 D00F A000 00F0          A2 AND B011 C=A2           %CLEAR LIMITS BIT                      15110C00 D
055E  22F0 0000 0000 0040          OUTPUT-1=MPCR                                                     15120C00 D
                                 % ************************     COMPARE      **********************  15130C00 D
                                 OPR44:                       %C                                     15140C00 D
055F  0CF0 0000 0000 0060          YFETCH-1=CPCR              %Y VALUE = A3,MIR                      15150C00 D
0560  2490 0000 0000 0060          GETAB-1=CPCR               %RETURNS A-FIELD IN B&MAR              15160C00 D
0561  49C9 E000 0030 00F0          A3=MIR;SET LC1                                                    15170C00 D
0562  A809 0000 0000 00F0          MR1;IF RDC                                                        15180C00 D
0563  AC08 0000 0C0C 00F0          WHEN RDC THEN BEX          %A(A)                                  15190C00 D
0564  4809 0C40 1D3C C0F0          B=A3,BMI                   %A(A)=A3;Y=>B                          15200C00 D
0565  206C 00C0 0030 0040          SETCOMPARE-1=MPCR          %A3=A(A);B=(Y)                         15210C00 D
                                 %   ******************     COMPARE LIMITS     ********************  15220C00 D
                                 OPR45:                       % CL                                   15230C00 D
                                 %   IF Y BETWEEN A(A) AND A(A+1) OR = A(A) THEN CD WITHIN LIMITS    15240C00 C
                                 %   ELSE OUTSIDE OF LIMITS                                          15250C00 D
0566  0CF0 00C0 0000 0060          YFETCH-1 = CPCR            % Y VALUE => A3,MIR                     15260C00 D
0567  2490 0000 0000 0060          GETAB-1=CPCR               %RETURNS A-FIELD IN B&MAR              15270C00 D
0568  A809 0000 0000 00F0          MR1;IF RDC                                                        15280C00 D
0569  0A50 00C0 003C 00C0          IFETCH-1=AMPCR             %USE IDENTICAL CODE IN OPR74X5         15290C00 D
056A  AC08 0F46 0C0C 00F0          WHEN RDC THEN BMAR+1=MAR,BEX                                      15300C00 D
056B  4809 2F56 000C 00F0          LIT AND BMAR=MAR           %CONVERT A(B) TO A(0)                  15310C00 D
056C  A809 0C40 4000 00F0          B=A1;MR1;IF RDC            %A1=A(A)                               15320C00 D
056D  AFC8 0000 0C30 00F0          WHEN RDC THEN BEX;SET LC1                                         15330C00 D
056E  4849 0C40 1C00 00F0          B=A3;SET LC2               %%A3=A(A+1);SIGNAL REPEAT              15340C00 D
056F  4809 A000 0030 00F0          A1=MIR,BMI                 %MIR=A(A);B=(Y)                        15350C00 D
0570  0F10 0000 0030 0040          OPR74XX5-1=MPCR                                                   15360C00 D
                                 %   ******************     COMPARE MASKED     ********************  15370C00 D
                                 OPR46:                       % CM                                   15380C00 D
0571  0CF0 0000 0030 0060          YFETCH-1 = CPCR            % Y VALUE => A3,MIR                     15390C00 D
0572  2490 0000 0000 0060          GETAB-1=CPCR               %RETURNS A-FIELD IN B&MAR              15400C00 D
0573  A809 0000 0000 00F0          MR1; IF RDC                                                       15410C00 D
0574  AFC8 0F46 0C0C 00F0          WHEN RDC THEN BMAR+1=MAR,BEX;SET LC1                              15420C00 D
0575  4809 2F56 000C 00F0          LIT AND BMAR=MAR           %CONVERT A(B) TO A(0)                  15430C00 D
0576  A809 EC56 1000 00F0          A3 AND B = A3,MIR;MR1; IF RDC                                     15440C00 D
0577  AC08 0000 0CD0 00F0          WHEN RDC THEN BEX          % A(A+1) => B                          15450C00 D
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0578  4889 0C40 1090 00F0          B = A3,BMI                    % A3=(Y+1),B=(A)AND(Y)                  15460C00 D
0579  2860 0000 000C 0040          SETCOMPARE-1=MPCR             %A3=A(A) AND Y; B=A(A+1)                15470C00 D
                                 %  ********************     COMPARE GATED     ************************  15480C00 D
                                 0PR47:                        % C0                                     15490C00 D
057A  0CF0 0000 0000 0060          YFETCH-1 = CPCR               % Y VALUE => A3,MIR                      15500C00 D
057B  2490 0000 0090 0060          GETAB-1=CPCR                  %RETURNS A-FIELD IN B&MAR               15510C00 D
057C  A005 0000 0090 00F0          MR1; IF RDC                                                           15520C00 D
057D  AFC8 0F46 0C0C C0F0          WHEN RDC THEN BMAR+1=MAR,BEX;SET LC1                                  15530C00 D
057E  4889 2F56 000C 00F0          LIT AND BMAR=MAR              %CONVERT A(B) TO A(B)                   15540C00 D
057F  7489 EC58 1B90 00F0          IF NOT AOV THEN A3-B-1=A3,B                                           15550C00 D
0580  A889 EC5E 1B90 00F0          A3-B=A3,B;MR1;IF RDC          %TAKE DIFFERENCE                        15560C00 D
0581  7489 E0DE 1B90 00F0          IF NOT AOV THEN A3-1=A3,B                                             15570C00 D
0582  9C09 0C42 1000 00F0          IF MST THEN NOT B=A3          %PUT ABSOLUTE VALUE IN A3               15580C00 D
0583  AC08 0008 0C70 00F0          WHEN RDC THEN BEX             %READ A(A+1)                            15590C00 D
0584  2860 0000 000C 0040          SETCOMPARE-1=MPCR             %A3=ABS(Y-A(A)); B=A(A+1)               15600C00 D
                                 % ************************     JUMP PARITY / DOUBLE PRECISION     ******  15610C00 D
                                 0PR50:                                                                15620C00 D
0585  1270 0000 0090 0060          Y2FETCH-1=CPCR                %BMAR=Y-ADDRESS                         15630C00 D
0586  24F0 0000 0090 0060          GETF1-1=CPCR                  %F1-FIELD IN A3                         15640000 D
0587  4889 E640 0090 C0F0          A3+AMPCR=AMPCR                                                        15650C00 D
0588  060C 00C0 0030 00C0          0PR50XX-1=AMPCR                                                       15660C00 D
0589  4889 A000 8800. 00F0         A1 R=B                        %ISOLATE A-FIELD                        15670C00 D
058A  8070 0000 0090 00A0          23=SAR;7=LIT                                                          15680C00 D
058B  4824 0F40 4090 C0F0          BMAR=A1;EXEC                                                          15690C00 D
058C  4889 2C56 0C0C 00F0          LIT AND B=MAR                 %READ A(A)                              15700C00 D
058D  A889 00C0 0030 C0F0          MR1;IF RDC                                                            15710C00 D
058E  AC08 0F46 0C3C 00F0          WHEN RDC THEN BMAR+1=MAR,BEX                                          15720C00 D
058F  482D 2F56 000C 00F0          LIT AND BMAR=MAR;JUMP         %A(B)=A(B)                              15730C00 D
                                   %A3=Y-ADDRESS; B=(A(A))                                             15740000 D
                                 %************************     JUMP ON CONDITIONS     ****************** 15750C00 D
                                 0PR51:                                                                15760C00 D
0590  1270 0000 0090 0060          Y2FETCH-1=CPCR                %RETURNS JUMP ADDR. IN BMAR             15770C00 D
0591  24F0 0000 0090 0060          GETF1-1=CPCR                  %RETURNS F1 FOR TYPE 3 IN A3            15780C00 D
0592  4889 E640 0090 C0F0          A3+AMPCR=AMPCR                                                        15790C00 D
0593  0780 0000 0030 00C0          0PR51XX-1=AMPCR               %SETUP FOR SUB OPCODE                   15800C00 D
0594  4889 0F40 1090 C0F0        BMAR=A3                                                                 15810C00 D
0595  4889 A000 8B30 00F0        A1 R=B                                                                  15820C00 D
0596  8070 0000 0090 00A0          23 = SAR; 7 = LIT                                                     15830C00 D
0597  4889 2C56 000C 00F0          LIT AND B=MAR                                                         15840C00 D
0598  A824 0000 0090 08F0          EXEC;MR1;IF RDC                                                       15850000 C
0599  AC28 00C0 0C00 C0F0          WHEN RDC THEN BEX;JUMP                                                15860C00 D
                                   %LEAVES (A) IN B; JUMP ADDRESS IN A3                                15870C00 D
                                 % ************************          JUMP AND INDEX       ************** 15880C00 D
                                 0PR52:                                                                15890C00 D
059A  1270 0000 0090 0060          Y2FETCH-1=CPCR                %JUMP ADDRESS IN BMAR                   15900C00 D
059B  24FC 0000 009C 0060          GETF1-1=CPCR                  %F1-FIELD IN A3                         15910C00 D
059C  4889 E640 0090 00F0          A3+AMPCR=AMPCR                                                        15920C00 D
059D  0780 0000 0090 00C0          0PR52XX-1=AMPCR                                                       15930C00 D
059E  4889 0F40 0B90 00F0          BMAR=B                        %JUMP ADDRESS IN B                      15940C00 D
059F  4889 A000 9000 00F0          A1 R=A3                       %ISOLATE B-FIELD                        15950C00 D
05A0  8070 0000 0090 00A0          23=SAR;7=LIT                                                          15960C00 D
05A1  4889 E156 5080 00F0          A3 AND LIT = A3,A1, MIR                                               15970C00 D
05A2  4889 E140 009C 00F0          A3+LIT=MAR                                                            15980C00 D
05A3  0888 0000 0030 00E0          BBASE=LIT                     %MAR1=ADDRESS OF B(A)                   15990C00 D
05A4  A824 0000 0090 08F0          EXEC;MR1;IF RDC                                                       16000C0C D
05A5  AC28 0C40 1C90 00F0          WHEN RDC THEN B=A3,BEX;JUMP                                           16010C00 D
                                   %B=(B(A)); A3=JUMP ADDRESS                                          16020C00 D
                                 % ************************       JUMP ON CO          ***************** 16030C00 D
                                 0PR53:                                                                16040C00 D
05A6  1270 0000 0090 006C          Y2FETCH-1=CPCR                %JUMP ADDR. IN BMAR                     16050C00 D
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05A7  24F0 0000 0030 0060        GETF1-1=CPCR              %RETURNS F1 FIELD IN A3                16060C00 D
05A8  4809 E640 0040 00F0        A3+AMPCR=AMPCR                                                   16070C00 D
05A9  0800 0000 0000 00C0        OPR53XX-1=AMPCR                                                  16080C00 D
05AA  4809 A000 9000 00F0        A1 R=A3                                                          16090000 D
05AB  3070 0000 000C C0A0        23=SAR;7=LIT                                                     16100000 D
05AC  4824 E156 0B00 C0F0        A3 AND LIT=B;EXEC                                                16110000 D
05AD  482D 0F40 1000 00F0        BMAR=A3;JUMP              %JUMP ADDR. IN A3;A-FIELD IN B         16120C00 D
                               % ########################    LOAD CMR TASK              ############16130000 D
                               OPR54:                                                             16140000 D
05AE  1270 000C 0030 0060        Y2FETCH-1=CPCR            %MIR=(Y)                               16150000 D
05AF  4809 0C40 0030 00F0        OPR54XX:  B=MIR           %ENTRY FOR OPR55                       16160C00 D
05B0  4809 A0C1 1000 00F0        A1 L=A3                   %ISOLATE AK-FIELDS                     16170C00 D
05B1  2000 0000 000C 0030        COMP 6=SAR                                                       16180C00 D
05B2  A809 E000 900C 00FC        A3 R=A3,MAR;IF RDC                                               16190C00 D
05B3  2400 00C0 0000 00B0        26=SAR;64=LIT             %64= 100 OCTAL OFFSET                  16200C00 D
05B4  3C09 E140 100C 00F0        IF LC2 THEN A3+LIT=A3,MAR %LC2=>OPR55 SO OFFEST BY 100           16210C00 D
05B5  2520 0000 0C00 0060        CHECKCMR-1=CPCR           %RETURNS LC1 IF LEGAL                  16220C00 D
05B6  2019 0000 0030 00F0        IF NOT LC1 THEN SKIP                                             16230C00 D
05B7  22F0 0000 0000 C040        OUTPUT-1=MPCR                                                    16240000 D
05B8  2210 0000 000C 0040        ILLEGALCMR-1=MPCR                                                16250C00 D
                               % ########################    STORE CMR TASK             ############16260C0C D
                               OPR55:                                                             16270C00 D
05B9  1270 0000 0000 0060        Y2FETCH-1=CPCR            %B=(Y)                                 16280C00 D
05BA  49C9 0000 0000 C0F0        SET LC1                   %PRIVILEGED                            16290C00 D
05BB  4849 0000 000C 00F0        SET LC2                   %SIGNAL TO OPR54 WHOSE CODE IS USED    16300000 D
05BC  5AE0 0000 0C30 004C        OPR54XX-1=MPCR                                                   16310C00 D
                               % ########################    STORE CMR INTERRUPT        ############16320C00 D
                               OPR56:                                                             16330C00 D
05BD  1270 0000 0000 0060        Y2FETCH-1=CPCR                                                   16340C00 D
05BE  4809 0F40 0030 00F0        OPR56XX:  BMAR=MIR                                               16350C00 D
05BF  4809 A0C1 1000 00F0        A1 L=A3                   %ISOLATE AK-FIELDS                     16360000 D
05C0  2000 0000 0000 C030        COMP 6=SAR                                                       16370C00 D
05C1  A809 E000 900C C0F0        A3 R=MAR,A3; IF RDC                                              16380C00 D
05C2  2400 0000 000C 00B0        26=SAR;64=LIT                                                    16390C0C D
05C3  3C09 E140 100C 00F0        IF LC2 THEN A3+LIT=A3,MAR %LC2=>OFFSET BY 100 OCTAL              16400000 D
05C4  2520 0000 0000 006C        CHECKCMR-1=CPCR           %RETURNS LC1 IF LEGAL                  16410C00 D
05C5  2E19 0000 0D00 08F0        IF LC1 THEN MR1;BMI;SKIP                                         16420C00 D
05C6  2210 0000 0030 0040        ILLEGALCMR-1=MPCR         %RETURNS TO IFFETCH AFTER PRINTING     16430C00 D
05C7  AC08 0C40 0C1C 00F0        WHEN RDC THEN B=MAR2,BEX                                         16440C00 D
05C8  4809 0C40 0030 00F0        B=MIR                                                            16450000 D
05C9  2370 0000 C030 C040        YOUT-1=MPCR                                                      16460C00 D
                               % ########################    LOAD CMR INTERRUPT         ############16470C00 D
                               OPR57:                                                             16480C00 D
05CA  1270 0000 0030 0060        Y2FETCH-1=CPCR                                                   16490C00 D
05CB  49C9 0000 0030 00F0        SET LC1                   %PRIVILEGEC                            16500C00 D
05CC  4849 0000 000C 00F0        SET LC2                   %SIGNALS OPR56 WHOSE CODE IS USED      16510C00 D
05CD  5BD0 0000 0030 0040        OPR56XX-1=MPCR            %SAME CODE OFFESET BY 100 OCTAL        16520C00 D
                               % ########################     STORE CMR IN A REGISTER    ########### 16530000 D
                               OPR60:  %IF I=1THEN OFFSET BY 100 OCTAL                            16540C00 D
05CE  4809 A001 1000 20F0        A1 L=A3;ASR               %VOID OPCODE AND SELECT BMAR1          16550C00 D
05CF  2000 0000 0030 0030        COMP 6=SAR                                                       16560C00 D
05D0  4809 E000 9000 00F0        A3 R=A3                   %A3=A,F4,B,I                           16570C00 D
05D1  A000 0000 0030 C020        22=SAR                                                           16580C00 D
05D2  4809 E000 800C 00F0        A3 R=MAR                  %MAR=CMR WITHOUT OFFSET                16590C00 D
05D3  0400 0000 0000 0080        4=SAR;64=LIT              %64=OFFSET OF 100 OCTAL                16600C00 D
05D4  5FC9 2F40 003C C0F0        IF LST THEN LIT+BMAR=MAR;SET LC1  %IF I=LSB =1 THEN OFFSET       16610C00 D
05D5  2520 0000 0030 0060        CHECKCMR-1=CPCR                                                  16620000 D
05D6  A809 E156 9000 08F0        A3 AND LIT R=A3;MR1;IF RDC                                       16630C00 D
05D7  10E0 0000 0000 0080        14=LIT;1=SAR              %MASK B-FIELD AND SAVE                 16640C00 D
05D8  AC08 E000 0C3C 00F0        WHEN RDC THEN A3=MAR,BEX  %B=(CMR)                               16650000 D
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05D9  4809 0C40 0090 00F0          B=MIR                    %SETUP TO WRITE (CMR TO A(B)        16660C00 D
05DA  2019 0000 0C00 00F0          IF LC1 THEN SKIP                                             16670C00 D
05DB  2200 0000 003C 0040          ILLEGALCMR1-1=MPCR                                           16680C00 D
05DC  0BB0 0000 0000 0040          HALFFETCH-1=MPCR         %MAR=ADDRESS OF A(B)                16690000 D
% ********************       LOAD CMR WITH (A-REG)       ***********  16700C00 D
OPR61:  %IF I=1 THEN OFFSET BY 100 OCTAL                                                        16710C00 D
05DD  4809 A001 1030 00F0          A1 L=A                   %VOID OPCODE FIELD                  16720C00 D
05DE  2000 0000 0030 C03C          COMP 6=SAR                                                   16730C00 D
05DF  4809 E000 9090 00F0          A3 R=A3                  %A3=A,F4,B,I                        16740C00 D
05E0  A0EC 0000 0000 00A0          22=SAR;14=LIT            %BMASK IS 14                        16750C00 D
05E1  4809 E156 003C 00F0          A3 AND LIT R=MAR         %MAR=ADDR OF A(B)                   16760C00 D
05E2  10E0 0000 0000 0000          1=SAR;14=LIT                                                 16770C00 D
05E3  A809 0000 0C90 C0F0          MR1;IF RDC                                                   16780C00 D
05E4  AC08 E000 9C9C 00F0          WHEN RDC THEN A3 R=A3,MAR,BEX                                16790C00 D
05E5  0400 0000 0090 0000          4=SAR;64=LIT                                                 16800C00 D
05E6  5FC9 E140 109C 00F0          IF LST THEN A3+LIT=A3,MAR;SET LC1                            16810000 D
05E7  4809 0C40 0090 00F0          B=MIR                    %B=(AIREG) TO BE WRITTEN            16820C00 D
05E8  252C 0000 0030 0060          CHECKCMR-1=CPCR          %RETURNS LC1 IF LEGAL               16830C00 D
05E9  2819 0000 0C00 C0F0          IF LC1 THEN SKIP                                             16840000 D
05EA  220C 0C00 0090 0040          ILLEGALCMR1-1=MPCR                                           16850C00 D
05EB  0BB0 0000 0000 0040          HALFFETCH-1=MPCR         %MAR=ADDR OF CMR(AF)                16860000 D
% ********************       SHIFT LEFT CIRCULAR      ************  16870C00 D
OPR62:  %SHIFT AMOUNT IN SAR;B=(A);MAR= ADDR OF A-REG                                           16880C00 D
05EC  26D0 00C0 0090 C060          SHIFTAMOUNT-1=CPCR                                           16890C00 D
05ED  4809 0000 0000 40F0          CSAR                     %COMPLEMENT FOR SHIFT LEFT          16900C00 D
05EE  4809 0C41 8080 C0F0          B C=MIR                                                      16910C00 D
05EF  0BB0 0000 0000 0040          HALFFETCH-1=MPCR          %MAR=A ADDRESS                     16920C00 D
% ********************    SHIFT LEFT CIRC/DOUBLE      ************16930C00 D
OPR63:                                                                                          16940000 D
                                   %SAMPLE INPUT A+1=ZZWW, A=XXYY; OUTPUT A+1=WWXX A=YYZZ       16950000 D
05F0  26D0 0000 0090 0060          SHIFTAMOUNT-1=CPCR       %B=(A-RE\);MAR=A-ADDR;SAR=SHIFTAMOUNT16960C00 D
05F1  4809 0C40 1000 00F0          B=A3                     %A3=XXYY                            16970C00 D
05F2  4809 0019 0B00 40F0          B111 L=B,CSAR            %B=FF00                             16980C00 D
05F3  4809 0F46 0C0C 00F0          BMAR+1=MAR               %SETUP FOR A+1                      16990C00 D
05F4  4809 2F56 000C C0F0          LIT AND BMAR=MAR         %CONVERT A(B) TO A(0)               17000C00 D
05F5  0070 0000 0090 00E0          7=LIT                                                        17010C00 D
05F6  A809 EC56 8080 08F0          A3 AND B R=MIR;MR1;IF RDC %MIR=00XX                          17020C00 D
05F7  AC08 E001 1C00 C0F0          WHEN RDC THEN A3 L=A3,BEX %B=ZZWW;A3=YY0C                    17030C00 D
05F8  4809 0C41 0F9C C0F0          B L=BBI                  %B=WWXX                             17040C00 D
05F9  4809 0C40 0C90 00F0          B=MIR,BEX                %B=ZZWW;7IR=WWXX=NEW(A+1)           17050C00 D
05FA  2019 000D 0090 00F0          IF NOT LC1 THEN SKIP                                         17060C00 D
05FB  0F20 00C0 0000 0040          OPR63XX-1=MPCR                                               17070C00 D
05FC  9809 0C40 8B00 18F0          B R=B;MW1;IF SAI          %B=00ZZ                            17080C00 D
05FD  9C08 0B02 803C 00F0          WHEN SAI THEN NOT CTR R=MAR                                  17090C00 D
05FE  0000 00C8 0C90 003C          24=SAR                                                       17100C00 D
05FF  4809 EC5C 0090 00F0          A3 OR B=MIR              %MIR=YYZZ                           17110C00 D
0600  0BB0 0000 0090 0040          HALFFETCH-1=MPCR          %(A)=YYZZ                          17120C00 D
OPR63XX:    B R=B                                                                               17130000 D
0602  4809 EC5C 0D90 00F0          A3 OR B=MIR,BMI                                              17140C00 D
0603  9809 0000 0000 18F0          MW1;IF SAI                                                   17150C00 D
0604  9C08 0C40 0C90 00FC          WHEN SAI THEN B=MIR                                          17160C00 D
0605  4809 0B02 803C 00F0          NOT CTR R=MAR                                                17170000 D
0606  0000 0000 0C90 0030          24=SAR                                                       17180C00 D
0607  0BBC 0000 0090 0040          HALFFETCH-1=MPCR                                             17190C00 D
% ********************       SHIFT RIGHT FILL WITH ZEROS     *******  17200C00 D
OPR64:      %SAR=SHIFT AMOUNT;B=(A);MAR=A ADDRESS                                               17210C00 D
0608  26D0 00C0 0090 C060          SHIFTAMOUNT-1=CPCR                                           17220C00 D
0609  4809 0C40 8090 00F0          B R=MIR                                                      17230000 D
060A  0BB0 0000 0C90 0040          HALFFETCH-1=MPCR          %MAR=A-REG ADDRESS                 17240C00 D
% ********************    SHIFT RIGHT DBL/FILL ZEROS   ************17250000 D
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                                 OPR65:                                                                          17260C00 D
                                         %EXAMPLE INPUT A+1=ZZWW, A=XXYY; OUPUT A+1=00ZZ, A=WWXX                  17270C00 D
0C0B  26D0 0000 0090 0060        SHIFTAMOUNT-1=CPCR              %B=A-REG;MAR=A-ADDR;SAR=SHIFT AMOUNT            17280C00 D
0C0C  9809 0F46 0C9C 00F0        BMAR+1=MAR                      %READ A+1                                       17290C00 D
0C0D  9809 2F56 000C 00F0        LIT AND BMAR=MAR                %CONVERT A(8) TO A(0)                           17300C00 D
0C0E  0070 0000 0090 00E0        7=LIT                                                                           17310C00 D
0C0F  2019 00C0 0090 00F0        IF NOT LC1 THEN SKIP                                                            17320C00 D
0610  0F30 0000 0000 0040        OPR65XX-1=MPCR                                                                  17330C00 D
0611  A809 0C40 900C 08F0        B R=A3;MR1;IF RDC               %A3=00XX                                        17340C00 D
0612  AC08 0000 0C90 00F0        WHEN RDC THEN BEX               %B=ZZWW                                         17350C00 D
0613  9809 0C40 8C90 00F0        B R=MIR,BEX                     %MIR=00ZZ;A3=00XX;B=ZZWW                        17360C00 D
0614  9809 CC41 0B30 18F0        B L=B;MW1;IF SAI                                                                17370000 D
0615  9E08 EC5C 0090 20F0        WHEN SAI THEN A3 OR B=MIR;ASR                                                   17380000 D
0616  9809 CBC2 809C 00F0        NOT CTR R=MAR                   %RESET A-ADDRESS                                17390C00 D
0617  0000 0000 0090 0030        24=SAR                          %B=WWXX                                         17400C00 D
0618  0B8C 0000 0090 C040        HALFFETCH-1=MPCR                                                                17410C00 D
0619  A809 0000 0090 08F0  OPR65XX:  0=MIR;MR1;IF RDC                                                           17420C00 D
061A  AC08 0000 0C90 C0F0        WHEN RDC THEN BEX                                                               17430C00 D
061B  9809 0000 0090 18F0        MW1;IF SAI                                                                      17440000 D
061C  9C08 0C40 8090 00F0        WHEN SAI THEN B R=MIR                                                           17450C00 D
061D  9809 CB02 809C C0F0        NOT CTR R=MAR                                                                   17460C00 D
061E  0000 0000 0090 0030        24=SAR                                                                          17470C00 D
061F  0B80 00C0 0000 C040        HALFFETCH-1=MPCR                                                                17480C00 D
                                 % ##########################      SHIFT RIGHT SIGN FILL      ##############      17490C00 D
                                 OPR66:      %SAR=SHIFT AMOUNT;MAR=AIREG ADDR; B=(A)                             17500C00 D
0620  26D0 0000 C090 0060        SHIFTAMOUNT-1=CPCR                                                              17510C00 D
0621  9809 0C40 8090 40F0        B R=MIR,CSAR                    %SAR SET FOR SIGN 1 EXTENSION                   17520C00 D
0622  0B80 0000 9090 00CC        HALFFETCH-1=AMPCR                                                               17530000 D
0623  9C0D 0019 0F00 00F0        IF MST THEN B111 L=BBI;STEP ELSE JUMP                                           17540000 D
0624  982D 0C40 0090 00F0        B=MIR;JUMP                      %NEGATIVE SIGN EXTENSION                        17550C00 D
                                 % ########################     SHIFT RIGHT DBLE/FILL SIGN    ##############17560C00 D
                                 OPR67:                                                                          17570C00 D
                                         %EXAMPLE INPUT A+1=ZZWW,A=XXYY; OUT&UT=A+1=00ZZ,A=WWXX                  17580000 D
                                         %EXAMPLE INPUT=-ZZWW;A=XXYY; OUTPUT=A+1=FFZZ, A=WWXX                    17590C00 D
0625  26D0 00C0 0090 0060        SHIFTAMOUNT-1=CPCR                                                              17600C00 D
0626  9809 0F46 009C 00F0        BMAR+1=MAR                                                                      17610C00 D
0627  9809 2F56 000C 00F0        LIT AND BMAR=MAR                %CONVERT A(8) TO A(0)                           17620000 D
0628  007C 0000 0090 00E0        7=LIT                                                                           17630C00 D
0629  2019 0000 0000 00F0        IF NOT LC1 THEN SKIP                                                            17640C00 D
062A  0F40 0000 0090 0040        OPR67XX-1=MPCR                                                                  17650C00 D
062B  A809 0C40 9C00 08F0        B R=A3;MR1;IF RDC               %A3=00XX                                        17660C00 D
062C  AC08 0000 0C90 00F0        WHEN RDC THEN BEX               %B=ZZWW                                         17670C00 D
062D  9809 0C40 8090 C0F0        B R=MIR                         %MIR=00ZZ                                       17680C00 D
062E  9C0B 0C19 0F00 C0FC        IF MST THEN B111 L=BBI; STEP ELSE SKIP  %CHECK FOR NEGATIVE                     17690C00 D
062F  9809 CC40 0C90 C0F0        B=MIR;BEX                       %B=ZZWW;A3=00XX;MIR=00ZZ                        17700C00 D
0630  9809 0C41 0B30 18F0        B L=B;MW1;IF SAI                %B=WW0C                                         17710C0C D
0631  9E08 EC5C 0090 20F0        WHEN SAI THEN A3 OR B=MIR;ASR  %MIR=WWXX                                        17720C00 D
0632  9809 0B02 809C 00F0        NOT CTR R=MAR                   %RESET A-ADDRESS                                17730C00 D
0633  0000 00C0 0090 0030        24=SAR                          %OUTPUT=WWXX                                    1774C000 D
0634  0B80 0000 0090 C040        HALFFETCH-1=MPCR                %A+1=SIG(/ZZ                                    1775CC00 D
                                 OPR67XX:   %B=(A);SAR=SHIFT-32                                                  17760000 D
0635  A809 0000 0090 08F0        MR1;IF RDC                                                                      17770C00 D
0636  AC08 0000 1C00 00F0        WHEN RDC THEN 0=A3,BEX          %B=(A+1);MIR=(A SHIFTED)                        17780000 D
0637  9809 0C40 8C90 00F0        B R=MIR                                                                         17790C00 C
0638  9C0B 00C2 1000 00F0        IF MST THEN NOT 0=A3;STEP ELSE SKIP                                             17800000 D
0639  9818 0019 0F00 00F0        B111 L=BB1;SKIP                                                                 17810C00 D
063A  9809 0000 0D90 C0F0        BMI                                                                             1782CC00 D
063B  9809 E0C0 0090 C0F0        A3=MIR                                                                          17830C00 D
063C  9809 0000 0090 18F0        MW1;IF SAI                                                                      1784CC00 D
063D  9C08 0B02 8C9C 00F0        WHEN SAI THEN NOT CTR R=MAR                                                     17850C00 D
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063E  0000 0000 0090 0030          24=SAR                                                  17860C00 D
063F  9809 0C40 0090 00FC          B=MIR                                                   17870C00 D
0640  0000 0000 0090 0040          HALFFETCH-1=MPCR                                        17880C00 D
                                 % ************************    FLOATING POINT SETUPS         ***********  17890000 D
                                 OPR70:      %RETURN WITH B=(A);BMAR=A-REG ADDRESS                      17900C00 D
0641  24CC 0000 0090 0060          GETAA3-1=CPCR               %MAR,A3=A-FIELD             17910C00 D
0642  2460 0000 0090 0060          GETF-1=CPCR                 %RETURNS F2-FIELD IN A3     17920C00 D
0643  9809 E640 0090 00F0          A3 + AMPCR=AMPCR                                        17930C00 D
0644  0070 0000 0090 00C0          OPR70XX-1=AMPCR                                         17940C00 D
0645  A809 0000 0000 00F0          MR1;IF RDC                                              17950000 D
0646  9824 0000 0090 00F0          EXEC                                                    17960C00 D
0647  AC28 0000 0C00 00F0          WHEN RDC THEN BEX;JUMP      %B=(A);MAR=A-REG ADDRESS    17970C00 D
                                 % ************************      HALFWORD LOGICALS AND ARITH    *******  17980C00 D
                                 OPR71:      %B=(A(B));A3=(A(A));MAR=A-FIELD ADDR             17990C00 D
0648  2460 00C0 0090 0060          GETF-1=CPCR                 %RETURNS F2-FIELD IN A3     18000C00 D
0649  9809 E640 0090 00F0          A3+AMPCR=AMPCR                                          18010C00 D
064A  0F50 0000 0000 00C0          OPR71XX-1=AMPCR                                         18020000 D
064B  9809 A000 9090 00F0          A1 R=A3                                                 18030C00 D
064C  1070 0000 0090 00A0          17=SAR;7=LIT                                            18040C00 D
064D  9809 E156 00DC 00F0          A3 AND LIT=MAR              %ISOLATE B FOR A(B)         18050000 D
064E  A809 A000 9000 00F0          A1 R=A3;MR1;IF RDC          %READ A(B)                  18060C00 D
064F  0000 0000 0090 0020          23=SAR                      %ISOLATE A-FIELD            18070C00 D
0650  AC00 E156 0CDC 00F0          WHEN RDC THEN A3 AND LIT=MAR,BEX                        18080C00 D
0651  A809 0C40 0090 00F0          B=MIR;MR1;IF RDC            %MIR=A(B)                   18090C00 D
0652  AC00 0000 0C90 00F0          WHEN RDC THEN BEX                                       18100C00 D
0653  2809 0C40 1D00 00F0          B=A3,BMI;IF LC1             %A3=A(A);B=A(B);CLEAR LC1   18110000 D
0654  3824 0000 0090 00F0          EXEC;IF LC2                 %EXECUTE OPR71XX + F-FIELD;CLEAR LC2 18120000 D
0655  9809 0000 0090 00F0          0;STEP                      %RESET AOV AND ABT FLAGS    18130C00 D
0656  2C0B EC40 0090 00F0          IF LC1 THEN A3+B=MIR;STEP ELSE SKIP %OPR71X1            18140C00 D
0657  7C09 EC46 0090 00F0          IF AOV THEN A3+B+1=MIR                                  18150C00 D
0658  5C09 0000 9090 00F0          IF ABT THEN 0=MIR           %ELIMINATE NEGATIVE 0       18160C00 D
0659  3C0B EC5E 0090 00FC          IF LC2 THEN A3-B=MIR;STEP ELSE SKIP %OPR71X2            18170C00 D
065A  7409 EC5B 9090 00F0          IF NOT AOV THEN A3-B-1=MIR                              18180C00 D
065B  0B80 000D 0090 0040          HALFFETCH-1=MPCR            %MAR=A-REG ADDRESS          18190C00 D
                                 % ************************     HALFWORD LOGICAL SUBCODES     **********  18200C00 D
                                 OPR71XX:                                                   18210C00 D
065C  9809 EC5C 0090 00F0          A3 OR B=MIR                 %OPR71X0                    18220C00 D
065D  39C9 0000 0090 00F0          SET LC1;IF LC2                                          18230C00 D
065E  2849 00C0 0000 00F0          SET LC2;IF LC1                                          18240C00 D
065F  9809 EC4C 0090 00F0          A3 XOR B=MIR                %OPR71X3                    18250C00 D
0660  21D0 0000 0090 C040          ILLEGAL-1=MPCR              %INVALID INSTRUCTION        18260C00 D
0661  9809 EC56 0090 00F0          A3 AND B=MIR                %OPR71X5                    18270000 D
                                 % ************************     REGISTER OPERATIONS HALFWORD    ********  18280C00 D
                                 OPR74:  %PROVIDES B,MIR=A-FIELD; A3=B-FIELD                18290C0C D
0662  2460 0000 0090 0060          GETF-1=CPCR                 %RETURNS F2-FIELD IN A3     18300C00 D
0663  9809 E640 0090 00F0          A3+AMPCR=AMPCR              %SETUP SUBOPCODE            18310C00 D
0664  08F0 0000 0090 00C0          OPR74XX-1=AMPCR                                         18320C00 D
0665  9809 A000 9000 00F0          A1 R=A3                                                 18330C00 C
0666  0070 0000 0090 00A0          23=SAR;7=LIT                                            18340C00 D
0667  9824 E156 0B90 00F0          A3 AND LIT=MIR,B;EXEC                                   18350C00 D
0668  9809 A000 9C00 00F0          A1 R=A3                                                 18360000 D
0669  1000 00C0 0090 0020          17=SAR                      %ISOLATE B-FIELD            18370C00 D
066A  482D E156 1090 00F0          A3 AND LIT=A3;JUMP                                      18380C00 D
                                 % ************************     INTERRUPT HANDLERS          ***********  18390C00 D
                                 OPR77:                                                     18400C00 D
066B  2460 0000 0090 0060          GETF-1=CPCR                 %A3=F-FIELD                 18410000 D
066C  9809 E640 0090 00F0          A3+AMPCR=AMPCR                                          18420C00 D
066D  097C 0000 0090 00C0          OPR77XX-1=AMPCR                                         18430C00 D
066E  9809 0000 0090 00F0          STEP                        %ALLOW TIME FOR AMPCR TO SET 18440C00 C
066F  9824 00C0 0090 00F0          EXEC                                                    18450C00 D
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0670  482D 0008 0080 00F0          JUMP                        %JUMP TO SUBOPCODE IN AMPCR          18460000 D
                                %  ########################      INCLUSIVE OR  (A OR )       ##########  18470000 D
                                OPR01X0:                        %INCLUSIVE Y OR A => A               18480000 D
0671  4809 EC5C 0030 00F0          A3 OR B = MIR                                                    18490C00 D
0672  2410 0008 0080 0040          OUTLOGIC-1=MPCR                                                  18500000 D
                                %  ########################      SELECTIVE CLEAR A WITH Y=>A(A+1)  #####  18510C00 D
                                OPR01X1:                                                           18520000 D
                                      %SELECTIVE CLEAR A, A AND NOT Y = A                          18530000 D
0673  4809 EC44 0030 00F0          A3 NRI B = MIR                                                   18540000 D
0674  2410 0008 0080 0040          OUTLOGIC-1=MPCR                                                  18550C00 D
                                %  ########################        SELECTIVE SUBSTITUTE   ############  18560000 D
                                OPR01X2:    %MAR=ADDR OF A-REG; B=A(A);A3=(Y)                      18570C00 D
0675  4809 0F46 000C 00F0          BMAR+1=MAR                                                       18580C00 D
0676  4809 2F56 000C 00F0          LIT AND BMAR=MAR            %CONVERT A(B) TO A(0)                18590C00 D
0677  A809 E000 0030 08F0          A3=MIR;MR1;IF RDC           %READ A(A+1)                         18600C00 D
0678  AC08 0C42 1C00 00F0          WHEN RDC THEN NOT B=A3,BEX                                       18610C00 D
                                      %A3=NOT (A); B=(A+1); MIR=(Y)                                18620C00 D
0679  4809 EC56 0D30 00F0          A3 AND B=MIR,BMI                                                 18630C00 D
                                      %B=(Y); MIR=NOT (A) AND (A+1); A3=NOT (A)                    18640C00 D
067A  4809 EC49 0F00 00F0          A3 NRI B=BBI                %A3=(A) AND B= (Y)  OR MIR=NOT (A)   18650C00 D
067B  4809 0C40 0030 00F0          B=MIR                                                            18660C00 D
067C  2410 0008 0080 0040          OUTLOGIC-1=MPCR             % AND (A+1)                          18670C00 D
                                %  ########################    EXCLUSIVE OR   A XOR Y        ##########  18680C00 D
                                OPR01X3:                                                           18690C00 D
                                      % A XOR Y = A                                                18700000 D
067D  4809 EC4C 0030 00F0          A3 XOR B = MIR                                                   18710C00 D
067E  2410 0008 0080 0040          OUTLOGIC-1=MPCR                                                  18720000 D
                                %  ########################    AND  A(A+1)+A(A) AND Y => A(A+1)   ######  18730C00 D
                                OPR01X4:                                                           18740C00 D
                                      %A+1 + A AND Y =>A+1                                         18750C00 D
067F  4809 0F46 000C 00F0          BMAR+1=MAR                                                       18760C00 D
0680  4809 2F56 000C 00F0          LIT AND BMAR=MAR            %CONVERT A(B) TO A(0)                18770C00 D
0681  A809 EC56 1000 08F0          A3 AND B=A3;MR1;IF RDC                                           18780C00 D
0682  AC08 0008 0C90 00F0          WHEN RDC THEN BEX           %A+1=>B                              18790000 D
0683  4809 EC40 0C30 00F0          A3+B=MIR                    %STORE ANSWER IN A+1                 18800C00 D
0684  7C09 EC46 0030 00F0          IF AOV THEN A3+B+1=MIR                                           18810C00 D
0685  6C09 0008 0030 00F0          IF ABT THEN 0=MIR           %ELIMINATE NEGATIVE 0                18820C00 D
0686  2410 0008 000C 0040          OUTLOGIC-1=MPCR                                                  18830C00 D
                                %  ########################    AND  A(A) AND Y => A(A)       ##########  18840C00 D
                                OPR01X5:                                                           18850C00 D
                                      %A AND Y =>A                                                 18860000 D
0687  4809 EC56 0030 00F0          A3 AND B=MIR                                                     18870C00 D
0688  22F0 0008 0090 0040          OUTPUT-1=MPCR                                                    18880C00 D
                                %  ########################    AND SUBTRACT A(A+1)-Y AND A(A) => A(A+1) #  18890C00 D
                                OPR01X6:                                                           18900C00 D
                                      %A+1 - A AND Y => A+1                                        18910C00 D
0689  4809 0F46 000C 00F0          BMAR+1=MAR                                                       18920000 D
068A  4809 2F56 000C 00F0          LIT AND BMAR=MAR            %CONVERT A(B) TO A(0)                18930C00 D
068B  A809 EC56 0030 08F0          A3 AND B = MIR;MR1;IF RDC                                        18940C00 D
068C  AC08 0008 0C90 00F0          WHEN RDC THEN BEX                                                18950C00 D
068D  4809 0C40 1D00 00F0          B=A3,BMI                    %SWAP REGISTERS TO SUBTRACT          18960C00 D
068E  4809 EC5E 0030 00F0          A3-B=MIR                                                         18970C00 D
068F  7409 EC58 0030 00F0          IF NOT AOV THEN A3-B-1=MIR                                       18980C00 D
0690  2410 0008 0080 0040          OUTLOGIC-1=MPCR                                                  18990C00 D
                                %  ########################    AND  A(B) AND Y => A(A+1)     ##########19000C00 D
                                OPR01X7:                                                           19010C00 D
                                      %A AND Y => A+1                                              19020000 D
0691  4809 0F46 000C 00F0          BMAR+1=MAR                                                       19030C00 D
0692  4809 2F56 000C 00F0          LIT AND BMAR=MAR            %CONVERT A(B) TO A(0)                19040C00 D
0693  4809 EC56 0030 00F0          A3 AND B=MIR                                                     19050C00 D
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0694  2410 0000 0000 0040          OUTLOGIC-1=MPCR                                          19060C00 D
                                 % ************************    COUNT ONES                  ************19070C00 D
                                 OPR02X0:                          % Y=>A3, A(A)=>B          19080C00 D
0695  4809 E000 0B30 00F0          A3 = B                                                   19090C00 D
0696  2920 0000 0000 0060          COUNTONES-1=CPCR                                         19100C00 D
0697  22F0 0000 0090 0040          OUTPUT-1 = MPCR                                          19110000 D
                                 % ************************    EXECUTE REMOTE       ********19120000 D
                                 OPR02X2:                          % Y VALUE => A3           19130C00 D
0698  4809 E000 0B30 00F0          A3=B                              %REMOTE INSTR. SETUP FOR IFETCH 19140C00 D
0699  0AD0 00C0 0000 0040          IFETCHREMOTE-1=MPCR               %LET IFETCH EXECUTE      19150C00 D
                                 % ************************    EXECUTE REMOTE LOWER ********19160000 D
                                 OPR02X3:                          % A3 = Y VALUE            19170C00 D
069A  4809 E000 0C90 00F0          A3 R=AMPCR                        %SETUP OPCODE            19180C00 D
069B  23F0 0000 0030 C090          63=LIT;10=SAR                                            19190C00 D
069C  4809 2656 0040 00F0          LIT AND AMPCR=AMPCR                                      19200C00 D
069D  4809 E001 4030 00F0          A3 L=A1                                                  19210C00 D
069E  0000 0000 0000 C020          16 = SAR                                                 19220C00 D
069F  4824 C001 0B00 40F0          A2 C=B,CSAR;EXEC                  %SET LOWER HALF BIT ON 19230C00 D
06A0  0000 0000 0030 0020          20=SAR                                                   19240C00 D
06A1  4820 0CC1 A030 00F0          BTT1 C=A2;JUMP                    %RESET ASR TO NORMAL   19250C00 C
                                 % ************************    A(A+1) AND Y => Y       ******19260C00 D
                                 OPR02X4:                          % A(A)=>B, Y ADDR => MIR  19270C00 D
06A2  4809 0F46 0C0C 00F0          BMAR+1 = MAR                      % A(A+1)                19280C00 D
06A3  4809 2F56 000C C0F0          LIT AND BMAR=MAR                  %CONVERT A(0) TO A(0)    19290C00 D
06A4  A809 0000 0000 08F0          MR1; IF RDC                                              19300C00 D
06A5  AC08 0C40 1C00 00F0          WHEN RDC THEN B=A3,BEX            % A(A)=>A3, A(A+1)=>B   19310C00 D
06A6  4809 EC56 0D30 00F0          A3 AND B = MIR,BMI                                       19320C00 D
06A7  4809 0C40 001C 00F0          B = MAR2                                                 19330C00 D
06A8  2370 0000 0090 0040          YOUT-1=MPCR                                              19340C00 D
                                 % ************************    A(A)+A(A+1) => A(A+1) & Y    ********19350C00 D
                                 OPR02X5:                          % A(A)=>B, Y ADDR => MIR  19360C00 D
06A9  4809 0F46 000C 00F0          BMAR+1 = MAR                      % A(A+1)                19370C00 D
06AA  4809 2F56 000C 00F0          LIT AND BMAR=MAR                  %CONVERT A(0) TO A(0)    19380C00 D
06AB  A809 0000 000C 00F0          MR1; IF RDC                                              19390C00 D
06AC  AC08 0C40 1C0C 00F0          WHEN RDC THEN B = A3,BEX                                 19400000 D
06AD  4809 EC40 0B30 00F0          A3+B=B                                                   19410C00 D
06AE  7C09 0C46 0B00 00F0          IF AOV THEN B+1=B                                        19420C00 D
06AF  6C09 0C42 0B00 00F0          IF ABT THEN NOT B=B                                      19430C00 D
06B0  4809 0C40 0D30 00F0          B=MIR,BMI                                                19440C00 D
06B1  2300 0000 0090 006C          OUTPUT1-1 = CPCR                  % A(A)+A(A+1) => A(A+1) 19450C00 D
06B2  4809 0C40 001C 00F0          B = MAR2                                                 19460C00 D
06B3  2370 0000 0090 0040          YOUT-1=MPCR                                              19470C00 D
                                 % ************************    A(A+1)-A(A)   => A(A+1) & Y  ********19480C00 D
                                 OPR02X6:                          % A(A)=>B,ADDR Y => MIR   19490C00 D
06B4  4809 0F46 000C C0F0          BMAR+1 = MAR                      % A(A+1)                19500000 D
06B5  4809 2F56 000C 00F0          LIT AND BMAR=MAR                  %CONVERT A(0) TO A(0)    19510C00 D
06B6  A809 0000 0C00 C0F0          MR1; IF RDC                                              19520C00 D
06B7  AC08 0C40 1C00 C0F0          WHEN RDC THEN B=A3,BEX            %   A(A)=>A3, A(A+1)=> B 19530C00 D
06B8  4809 0C40 4000 00F0          B = A1                                                   19540C00 D
06B9  4809 E000 0B3C C0F0          A3 = B                                                   19550000 D
06BA  4809 AC5E 4C30 00F0          A1-B=A1                                                  19560C00 D
06BB  7409 A0DE 4000 00F0          IF NOT AOV THEN A1-1=A1                                  19570000 D
06BC  4809 A000 0D30 00F0          A1=MIR,BMI                                               19580C00 D
06BD  2300 0000 0090 C060          OUTPUT1-1=CPCR                                           19590000 D
06BE  4809 0C40 001C 00F0          B = MAR2                                                 19600C00 D
06BF  2370 0000 0090 0040          YOUT-1=MPCR                                              19610C00 D
                                 % ************************      DOUBLE STORE A         ******19620C00 D
                                 OPR02X7:  SB=(A(A));A3=(Y);MIR=Y-ADDRESS                  19630C00 D
06C0  4809 0F46 000C 00F0          BMAR+1=MAR                        %MAR=A+1               19640C00 D
06C1  4809 2F56 000C 00F0          LIT AND BMAR=MAR                  %CONVERT A(0) TO A(0)  19650C00 D
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06C2  A809 0C49 0D90 C0FC          B=MIR,BMI,MR1;IF RDC          $MIR=A(A);B=Y-ADDR                    19660C00 D
06C3  AC08 0C49 0C1C 00F0          WHEN RDC THEN B=MAR2,DEX      $B=(A(A+1));MAR2=Y                    19670C00 D
06C4  9809 00C8 009C 1CF0          MW2;IF SAI                                                          19680C00 D
06C5  9C08 0F46 001C 00F0          WHEN SAI THEN BMAR+1=MAR2                                           19690C00 D
06C6  9809 0C49 0C90 00F0          B=MIR                         $SETUP A+1 FOR OUTPUT                 19700C00 D
06C7  2328 C008 0090 0040          OUTPUT2NORET-1=MPCR                                                 19710C00 C
                                 $ ********************      TEST AND SET FLAG     ****************** 19720C00 D
                                 0PR03X7:                                                            19730C00 C
06C8  127C 0008 009C 0060          Y2FETCH-1=CPCR                $BMAR=YADDRESS; B=(Y)                 19740C00 D
06C9  9809 0C49 0090 00F0          B                             $TEST MOST SIGNIFICANT BIT            19750C00 D
06CA  9419 1C49 0090 00F0          IF NOT MST THEN BITT=MIR;SKIP                                       19760C00 D
06CB  0F6C 0008 0090 0040          0PR03XX7-1=MPCR                                                     19770C00 D
06CC  9809 0009 0090 1CF0          MW2;IF SAI                                                          19780C00 D
06CD  9C18 D01C 2C90 00F0          WHEN SAI THEN A2 OR B100=A2;SKIP                                    19790C00 D
06CE  9809 D00E 2C90 00F0          0PR03XX7:  A2 AND B011=A2                                           19800C00 D
06CF  0A5C 0008 0090 0040          IFETCH-1=MPCR                                                       19810C00 D
                                 $ ********************     DOUBLE LOAD A                ************19820C00 C
                                 0PR05X0:   $MIR=(Y);MAR2=YADDR                                      19830C00 C
06D0  9809 0F46 001C 00F0          BMAR+1=MAR2                   $READ Y+1                             19840C00 D
06D1  A809 0009 0090 0CF0          MR2;IF RDC                                                          19850C00 D
06D2  AC08 E0C9 0C9C 00F0          WHEN RDC THEN A3=MAR,DEX      $A3=A-ADDRESS                         19860C00 D
06D3  A809 0008 0090 10F0          MW1;IF RDC                    $WRITE Y                              19870C00 D
06D4  9C08 E0C8 009C C0F0          WHEN SAI THEN A3+1=MAR                                              19880C00 D
06D5  9809 2F56 009C 00F0          LIT AND BMAR=MAR              $CONVERT A(8) TO A(0)                 19890C00 D
06D6  9809 0C49 0C90 00F0          B=MIR                                                               19900C00 D
06D7  22F0 0008 0090 0040          OUTPUT-1=MPCR                 $WRITE Y+1                            19910C00 D
                                 $ ************************    DOUBLE ADD              **********  19920C00 D
                                 0PR05X1:  $A3=A-ADDRESS;MAR2=Y-ADDRESS;MIR=(Y)                      19930C00 D
06D8  9809 0F46 0D1C C0F0          BMAR+1=MAR2,BMI                                                     19940C00 D
06D9  A809 0C49 4090 0CF0          B=A1;MR2;IF RDC               $A1=(Y)                               19950C00 D
06DA  AC08 E0C8 0C3C 00F0          WHEN RDC THEN A3=MAR,DEX                                            19960000 D
06DB  A809 0C49 1090 08F0          B=A3;MR1;IF RDC               $A3=(Y+1)                             19970C00 D
06DC  AC08 0008 0C90 00F0          WHEN RDC THEN DEX             $B=(A)                                19980C00 D
06DD  9809 AC49 4090 08FC          A1+B=A1;MIR                   $A1=A+Y                               19990C00 D
06DE  7BC9 0F49 0B90 00F0          BMAR=B; IF AOV THEN SET LC1 $TEST FOR CARRY                         20000C00 D
06DF  9809 0F46 009C 00F0          BMAR+1=MAR                                                          20010000 D
06E0  9809 2F56 009C 00F0          LIT AND BMAR = MAR            $CONVERT A(8) TO A(0)                 20020000 D
06E1  A809 0008 0090 08F0          MR1;IF RDC                                                          20030C00 D
06E2  AC08 0C49 0C9C 00F0          WHEN RDC THEN B=MAR,DEX                                             20040C00 D
06E3  2C19 EC46 1090 00F0          IF LC1 THEN A3+B+1=A3;SKIP $ADD CARRY                               20050C00 D
06E4  9809 EC49 1090 C0F0          A3+B=A3                                                             20060000 D
06E5  7C09 A0C8 4090 C0F0          IF AOV THEN A1+1=A1,MIR       $ADD CARRY                            20070C00 D
06E6  9809 E0C2 0090 00F0          NOT A3                                                              20080C00 D
06E7  6C0B A0C2 0090 00F0          IF ABT THEN NOT A1;STEP ELSE SKIP                                   20090C00 D
06E8  6C09 0008 5090 C0F0          IF ABT THEN B=A1,A3,MIR                                             20100C00 D
06E9  9809 0008 0050 18F0          MW1;IF SAI                    $OUTPUT A+Y                           20110C00 D
06EA  9C08 0F46 009C 00F0          WHEN SAI THEN BMAR+1=MAR                                            20120C00 D
06EB  9809 2F56 009C 00F0          LIT AND BMAR=MAR              $CONVERT A(8) TO A(0)                 20130C00 D
06EC  9809 E009 0090 00F0          A3=MIR                                                              20140C00 D
06ED  22F0 00C9 0C9C 0040          OUTPUT-1=MPCR                 $OUTPUT (A+1)+(Y+1)                   20150C00 D
                                 $ ************************    DOUBLE SUBTRACT (A+1,A)-(Y+1,Y)=>A+1,A ***20160000 D
                                 0PR05X2:  $A3=A-ADDR;MAR2=Y-ADDR;MIR=(Y)                            20170000 C
06EE  9809 0F46 0D1C 00F0          BMAR+1=MAR2,BMI               $B=(Y)                                20180000 D
06EF  A809 0C49 4090 0CF0          B=A1;MR2;IF RDC               $A1=(Y)                               20190000 C
06F0  AC08 E0C8 0C3C 00F0          WHEN RDC THEN A3+1=MAR,DEX                                          20200C00 D
06F1  9809 2F56 009C 00F0          LIT AND BMAR=MAR              $CONVERT A(8) TO A(0)                 20210C00 D
06F2  A809 0C49 0090 08F0          B=MIR;MR1;IF RDC              $MIR=(Y+1);READ A+1                   20220000 D
06F3  AC08 E0C8 0C9C 00F0          WHEN RDC THEN A3=MAR,DEX      $B=(A+1)                              20230C00 D
06F4  9809 0C49 1D90 00F0          B=A3,BMI                      $A3=(A+1)                             20240C00 D
06F5  A809 EC5E 1090 08F0          A3-B=A3;MR1;IF RDC            $A3=(A+1)-(Y+1)                       20250C00 D
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06F6  73C9 0008 0090 00F0          IF NOT AOV THEN SET LC1                                    2C260C00 D
06F7  AC08 A0C8 0C90 00F0          WHEN RDC THEN A1=MIR,BEX   %B=(A)                          2C270C00 D
06F8  9809 0C40 9D00 00F0          B=A1,BMI                                                   2C280C00 D
06F9  2C19 AC58 9090 00F0          IF LC1 THEN A1-B-1=A1,MIR;SKIP                             2C290C00 D
06FA  9809 AC5E 9090 00F0          A1-B=A1,MIR                                                2C300C00 D
06FB  7408 E0DE 1000 00F0          IF NOT AOV THEN A3-1=A3;STEP ELSE SKIP                     2C310C00 D
06FC  7409 A0DE 9090 00F0          IF NOT AOV THEN A1-1=A1,MIR                                2032C000 C
06FD  9809 0003 0C0C 10F0          MW1;IF SAI                                                 20330C00 D
06FE  9C08 0F46 008C 00F0          WHEN SAI THEN BMAR+1=MAR   %WRITE A                        20340C00 D
06FF  9809 2F56 008C 00F0          LIT AND BMAR=MAR           %CONVERT A(8) TO A(0)           2C350000 D
0700  9809 E0C8 0090 00F0          A3=MIR                     %WRITE A+1                      2036CC00 D
0701  22FC 0008 0C0C 0040          OUTPUT-1=MPCR                                              2C370C00 D
                                 % ************************    DOUBLE COMPARE                ************2C380C00 D
                                 0PR05X3:                                                     2039CC00 D
0702  9809 0F46 001C 00F0          BMAR+1=MAR2                %MAR2=Y-ADDR;MIR=(Y);A3=A-ADDR  20400C00 D
0703  A809 C0C1 AD00 0CFC          A2 C=A2,BMI;MR2;IF RDC                                     2041C000 D
0704  B00C 00C8 0090 0030          COMP 1=SAR                 %MSB=GE;LSB=EQUAL BIT           20420C00 D
0705  9809 0C40 9000 00F0          B=A1                       %A1=Y                           20430C00 D
0706  AC08 E0C8 0C0C 00F0          WHEN RDC THEN A3=MAR,BEX   %B=Y+1;MAR=A                     20440C00 C
0707  A809 0C40 1090 08F0          B=A3;MR1;IF RDC                                            20450C00 D
0708  AC08 0F46 0C0C 00F0          WHEN RDC THEN BMAR+1=MAR,BEX  %A1=Y;A3=Y+1;B=A             20460C00 D
0709  9809 2F56 008C 00F0          LIT AND BMAR=MAR           %CONVERT A(8) TO A(0)           20470C00 D
070A  A809 AC52 0000 C0F0          A1 EQL B;MR1;IF RDC                                        2048CC00 D
070B  6BC9 AC4C 0090 00F0          A1 XOR B; IF TRUE THEN SET LC1  %TEST SIGNS;LC1 => A EQL Y  20490C00 D
070C  0A50 000B 0090 00C0          IFETCH-1=AMPCR                                             20500C00 C
070D  9808 AC5E 0090 40F0          A1 LSS B,CSAR; IF MST THEN STEP ELSE SKIP                  20510C00 D
070E  7A49 00C8 0080 00F0          IF FALSE THEN SET LC2      %SIGNS WERE DIFFERENT           20520C00 D
070F  7249 0003 0090 00F0          IF TRUE THEN SET LC2                                       20530C0C D
0710  AC08 00C8 0C90 00F0          WHEN RDC THEN BEX                                          20540C00 D
0711  9809 EC52 0000 00F0          A3 EQL B                                                   20550C00 D
0712  6408 C0CE 2090 C0F0          IF FALSE THEN A2 AND B110 = A2;STEP ELSE SKIP %CLEAR EQUAL BIT  20560C00 D
0713  0F70 00C8 0090 0040          0PR05XX3-1=MPCR                                            2057CC00 C
0714  2C0B C0DC 2C90 00F0          IF LC1 THEN A2 OR B001 =A2;STEP ELSE SKIP %A+1,A=Y+1,Y      20580C00 D
0715  982D D01D A090 C0F0          A2 OR B100 C=A2;JUMP       %SET GEQ BIT                    20590000 D
0716  3C19 D01C 2090 00F0          IF LC2 THEN A2 OR B100=A2;SKIP  %A+1,A GTR Y+1,Y SET GTR BIT  20600C00 D
0717  9809 D00E 2090 00F0          A2 AND B011=A2             %CLEAR GEQ BIT                  2061C000 D
0718  982D C0CF A090 00F0          A2 AND B110 C=A2;JUMP      %CLEAR EQUAL BIT                20620C00 D
                                 0PR05XX3:  %LOWER HALVES A&Y NOT EQUAL                       20630C00 D
0719  9809 EC4C 0090 00F0          A3 XOR B                                                   20640C00 D
071A  9819 EC5E 0090 00FC          A3 LSS B;IF MST THEN SKIP                                  20650C00 D
071B  7429 D01D A090 00F0          IF TRUE THEN A2 OR B100 C=A2;JUMP   %SET GEQ BIT           20660C00 D
071C  7C29 D01D A090 C0F0          IF FALSE THEN A2 OR B100 C=A2;JUMP                         20670C00 D
071D  982D D00F A090 00F0          A2 AND B011 C=A2;JUMP                                      20680C00 D
                                 % ************************    LOAD BASE & MEM.PROT.         ************20690C00 D
                                 0PR05X4:                                                     20700C00 D
071E  2240 0008 0090 C040          UNWRITTEN-1=MPCR           %PRINT ERROR AND RETURN TO IFETCH  20710C00 D
                                 % ************************    FLOATING POINT ADD            ************20720C00 D
                                 0PR06X0:                                                     20730C00 D
071F  9800 0008 0090 00F0          WAIT                                                       2C740C00 D
0720  0A50 0008 0090 0040          IFETCH-1=MPCR                                              20750C00 D
                                 % ************************    FLOATING POINT SUBTRACT       ************2C76CC00 D
                                 0PR06X1:                                                     20770C00 D
0721  980C 0008 0090 00F0          WAIT                                                       20780C00 D
0722  0A50 0008 0090 C040          IFETCH-1=MPCR                                              20790C00 D
                                 % ************************    FLOATING POINT MULTIPLY       ************2080CC00 D
                                 0PR06X2:                                                     2081CC00 D
0723  9800 0008 0090 00F0          WAIT                                                       20820C00 D
0724  0A50 0008 0090 0040          IFETCH-1=MPCR                                              20830C0C D
                                 % ************************    FLOATING POINT DIVIDE         ************2084CC00 D
                                 0PR06X3:                                                     2085CC00 D
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0725  9800 0000 0030 00F0          WAIT                                                          20860C00 D
0726  0A50 0000 0090 0040          IFETCH-1=MPCR                                                 20870000 D
                                $ ************************    FLOATING POINT ADD/ROUND     ************20880C00 D
                                0PR06X4:                                                        20890C00 D
0727  9800 0000 0000 00F0          WAIT                                                          20900C00 D
0728  0A50 0000 0090 0040          IFETCH-1=MPCR                                                 20910C00 D
                                $ ************************    FLOATING POINT SUBR/ROUND    ************20920000 D
                                0PR06X5:                                                        20930C00 D
0729  9800 0000 0000 00F0          WAIT                                                          20940C00 D
072A  0A50 0000 0090 0040          IFETCH-1=MPCR                                                 20950C00 D
                                $ ************************    FLOATING POINT MULT/ROUND    ************20960C00 D
                                0PR06X6:                                                        20970000 D
072B  9800 0000 0090 00F0          WAIT                                                          20980C00 D
072C  0A50 0000 0000 0040          IFETCH-1=MPCR                                                 20990C00 D
                                $ ************************    FLOATING POINT DIV/ROUND     ************21000C00 D
                                0PR06X7:                                                        21010000 D
072D  9800 0000 0000 00F0          WAIT                                                          21020C00 D
072E  0A50 0000 0090 0040          IFETCH-1=MPCR                                                 21030C00 D
                                $ ************************    INTERPROCESSOR INTERRUPT     ************21040C00 D
                                0PR07X0:                                                        21050C00 D
072F  2240 0000 0000 004C          UNWRITTEN-1=MPCR          $PRINT ERROR AND RETURN TO IFETCH   21060C00 D
                                $ ************************    ALLOW ENABLE INTERUPT        ************21070C00 D
                                0PR07X1:                                                        21080C00 D
0730  2240 0000 0090 0040          UNWRITTEN-1=MPCR          $PRINT ERROR AND RETURN TO IFETCH   21090C00 D
                                $ ************************    PREVENT ENABLE INTERRUPT     ************21100C00 D
                                0PR07X2:                                                        21110C00 D
0731  2240 0000 0090 0040          UNWRITTEN-1=MPCR          $PRINT ERROR AND RETURN TO IFETCH   21120C00 D
                                $ ************************    LOAD IOC MONITOR CLOCK       ************21130C00 D
                                0PR07X3:                                                        21140C00 D
0732  2240 0000 0090 0040          UNWRITTEN-1=MPCR          $PRINT ERROR AND RETURN TO IFETCH   21150C00 D
                                $ ************************      I/O ROUTINES      ************************21160C00 D
                                0PR07X4:                                                        21170C00 D
0733  9809 E012 0000 00F0          A3 EQL 0                                                      21180C00 D
0734  680B 0000 0090 00F0          IF TRUE THEN STEP ELSE SKIP                                   21190C00 D
0735  1F40 00C0 0090 0040          CARDREAD-1=MPCR                                               21200000 D
0736  9809 E0D2 0000 00F0          A3 EQL 1                                                      21210C00 D
0737  680B 0000 0090 00F0          IF TRUE THEN STEP ELSE SKIP                                   21220000 D
0738  1F80 0000 0090 0040          PRINTLINE-1=MPCR                                              21230C00 D
0739  1FC0 00C0 0090 0040          DISKREAD-1=MPCR                                               21240000 D
                                $ ************************    INTERRUPT RETURN             ************21250000 D
                                0PR07X5:                                                        21260C00 D
073A  2240 0000 0090 0040          UNWRITTEN-1=MPCR          $PRINT ERROR AND RETURN TO IFETCH   21270C00 D
                                $   ********************     REPEAT     ********************************21280C00 D
                                0PR07X6:                    $ RP                                21290C00 D
073B  98C9 0000 0098 00F0          LMAR;RESET GC2                                                21300C00 D
073C  00F0 00C0 0000 00E0          15 = LIT                                                      21310000 D
073D  A809 0000 0090 00F0          MR1; IF RDC               $ B(7)                              21320C00 D
073E  AC08 0000 0C90 00F0          WHEN RDC THEN BEX                                             21330C00 D
073F  9809 0C42 0000 00F0          NOT B                                                         21340C00 D
0740  6C0B C0C0 2090 00F0          IF ABT THEN A2 + 1 = A2 ELSE SKIP                             21350000 D
0741  0A50 00C0 0090 0040          IFETCH-1 = MPCR           $ SKIP N.I.                         21360000 D
0742  9809 0C40 1090 00F0          B = A3                                                        21370C00 D
0743  9809 E0DE 0090 00F0          A3-1 = MIR                                                    21380000 D
0744  2300 0000 0090 0060          OUTPUT1-1 = CPCR          $ DEC B(7)                          21390C00 D
0745  9809 C003 001C 00FC          A2 = MAR2                                                     21400C00 D
0746  A809 0000 0090 0CF0          MR2; IF RDC                                                   21410C00 D
0747  AC08 A0B0 0C90 00F0          WHEN RDC THEN A1=MIR,LMAR,BEX  $READ N.I.                     21420C00 D
0748  0180 00C0 0000 00E0          RINST=LIT                                                     21430C00 D
0749  2300 0000 0090 C060          OUTPUT1-1 = CPCR          $ SAVE REPEAT INST.                 21440C00 D
074A  9809 0F46 009C 00F0          BMAR + 1 = MAR                                                21450C00 D
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0748  4809 0C48 4090 C0F0          B = MIR,A1                                          21460C00 D
074C  230C 0000 0000 0060          OUTPUT1-1 = CPCR          % SAVE N.I.               21470C00 D
074D  4809 0C48 9000 00F0          B R = A3                                            21480C00 D
074E  2000 0003 0C00 0030          26 = SAR                                            21490C00 D
074F  3C1C 0000 0C00 0060          CONDCHECK-1 = CPCR        % OPCODE REPEATABLE ?     21500C00 D
0750  2E99 0001 A000 40F0          IF LC1 THEN A2 C = A2,CSAR;SET GC2; SKIP            21510C00 D
0751  0AAC 0000 0C00 C040          IFETCH1-1 = MPCR          % NOT REPEATABLE          21520C00 D
0752  9000 0000 0000 0020          21 = SAR                                            21530C00 D
0753  1800 0000 0000 00F0          SET GC2; WHEN GC2 THEN STEP                         21540C00 D
0754  4809 C0DD A000 C0F0          A2 OR B001 C = A2         % SET REPEAT FLAG         21550C00 D
0755  3000 0003 0030 0060          $6YFETCH-1 = CPCR                                   21560C00 D
0756  0AAC 0000 0030 C040          IFETCH1-1 = MPCR                                    21570C00 D
                                 % ************************     JUMP ON EVEN PARITY    ****************** 21580C00 D
                                 0PR50X0:    %A1=Y-ADDRESS; A3=A(A)                  21590C00 D
0757  A809 0C48 1000 00F0          B=A3;MR1;IF RDC           %READ  A(A+1) MAR=ADDRESS OF A+1  21600C00 D
0758  AC00 0000 0C30 00F0          WHEN RDC THEN BEX                                   21610C00 D
0759  4809 EC56 0000 00F0          A3 AND B=B                %A(A) AND A(A+1) = B      21620C00 D
075A  292C 00C0 000C 0060          COUNTONES-1=CPCR          %COUNTONES USES A3 FOR COUNTER  21630C00 D
075B  4809 E000 0000 00F0          A3                        %CHECK LSB FOR ODD        21640C00 D
075C  5819 0000 0000 C0F0          IF LST THEN SKIP                                    21650C00 D
075D  23C0 0000 0030 00F0          IF NOT LC1 THEN SET LC1; STEP ELSE SKIP             21660C00 D
075E  2809 0000 0030 00F0          IF LC1 THEN SET LC1; SKIP                           21670C00 D
075F  0A50 0000 0000 C040          IFETCH-1=MPCR                                       21680C00 D
0760  4809 A000 1000 00F0          A1=A3                     %PUT JUMP ADDRESS IN A3 FOR PUTJUMP  21690C00 D
0761  2660 0000 0000 0040          PUTJUMP-1=MPCR                                      21700C00 D
                                   %IF ODD(LST) AND NOT LC1(0PR50X0) => NO JUMP       21710C00 D
                                   %IF ODD(LST) AND LC1(0PR50X1) => JUMP;SET LC1 FOR PUTJUMP  21720C00 D
                                 % ************************     JUMP ON ODD PARITY  ****************** 21730C00 D
                                 0PR50X1:                    %USES 0PR50X0 ROUTINE WITH LC1 SET  21740C00 D
0762  49C9 0000 0000 C0F0          SET LC1                                             21750C00 D
0763  7560 0000 0000 0040          0PR50X0-1=MPCR                                      21760C00 D
                                 % ************************   JUMP IF A(A) AND A(A+1) EQUAL ZERO  ****** 21770C00 D
                                 0PR50X2:    %A1=JUMP ADDRESS;B=(A(A));MAR=A+1 ADDRESS  21780C00 D
0764  A809 0C52 0000 00F0          0 EQL B;MR1;IF RDC        %TEST A(A) FOR 0          21790C00 D
0765  6019 0000 0000 C0F0          IF FALSE THEN SKIP                                  21800C00 D
0766  AC00 0000 0C30 00F0          WHEN RDC THEN BEX                                   21810C00 D
0767  4809 0C52 0000 00F0          0 EQL B                                             21820C00 D
0768  6A49 0003 0000 00F0          IF TRUE THEN SET LC2      %TEST (A(A+1)=0           21830C00 D
0769  3819 0000 0000 00F0          IF LC2 THEN SKIP          %A(A) & A(A+1)=0          21840C00 D
076A  2809 0000 0030 00F0          IF LC1 THEN STEP ELSE SKIP                          21850C00 D
076B  2309 0000 0030 00F0          IF NOT LC1 THEN SET LC1; SKIP                       21860C00 D
076C  0A50 0000 0030 C040          IFETCH-1=MPCR                                       21870C00 D
076D  4809 A000 1000 00F0          A1=A3                     %SETUP JUMP ADDRESS FOR PUTJUMP  21880000 D
076E  2660 0000 0000 0040          PUTJUMP-1=MPCR                                      21890C00 D
                                   %IF A(A) AND A(A+1) = 0 AND 0PR50X2 => JUMP       21900C00 D
                                  %IF  A(A) AND A(A+1) = 0 AND 0PR50X3 => NO JUMP     21910C00 D
                                 % ************************    JUMP IF A(A+ OR A(A+1) NOT EQUAL ZERO  21920C00 D
                                 0PR50X3:    %USES SAME ROUTINES AS 0PR50X2 WITH LC1 SET  21930000 D
076F  49C9 0000 0000 00F0          SET LC1                                             21940000 D
0770  7630 0000 0000 0040          0PR50X2-1=MPCR                                      21950C00 D
                                 % ************************     JUMP (A) POSITIVE      ****************** 21960C00 D
                                 0PR51X0:                    %B=(A)                  21970C00 D
0771  4809 0C40 0030 00F0          B                                                   21980C00 D
0772  43C9 0000 0000 00F0          IF NOT MST THEN SET LC1                             21990C00 D
0773  2660 0000 0030 0040          PUTJUMP-1=MPCR                                      22000C00 D
                                 % ************************      JUMP (A) NEGATIVE     ****************** 22010C00 D
                                 0PR51X1:                                            22020C00 D
0774  4809 0C42 0800 00F0          NOT B=B                   %SAME AS 51X0 EXCEPT COMPLEMENT B  22030000 D
0775  7700 0000 0030 0040          0PR51X0-1=MPCR                                      22040C00 D
                                 % ************************    JUMP (A) ZERO       ********************** 22050C00 D
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                             OPR51X2:                                                                   22060000 D
0776  4009 0C42 0000 00F0           NOT B                                                               22070000 D
0777  6BC9 0000 0000 00F0           IF ABT THEN SET LC1                                                 22080000 D
0778  266C 0000 0C00 0040           PUTJUMP-1=MPCR                                                      22090000 D
                             $ **********************      JUMP (A) NOT ZERO      ****************      22100000 D
                             OPR51X3:                                                                   22110000 D
0779  4009 0C42 0000 00F0           NOT B                                                               22120000 D
077A  63C9 0000 0C00 00F0           IF NOT ABT THEN SET LC1                                             22130000 D
077B  2660 0000 0000 0040           PUTJUMP-1=MPCR                                                      22140000 D
                             $ **********************        LOAD B AND JUMP      ***************       22150000 D
                             OPR52X0:                             $JUMP ADDR. IN A3;A1=B-FIELD          22160000 D
077C  4009 A012 0000 00F0           A1 EOL 0                                                            22170000 D
077D  67D9 C000 0000 00F0           IF FALSE THEN A2=MIR;SET LC1;SKIP  $MAR1=ADDR OF B(A)               22180000 D
077E  0A50 00C0 0000 0040           IFETCH-1=MPCR                                                       22190000 D
077F  2300 0000 0000 C060           OUTPUT1-1=CPCR                                                      22200000 D
0780  266C 0000 0000 0040           PUTJUMP-1=MPCR                                                      22210000 D
                             $ **********************        INDEX JUMP B         ***************       22220000 C
                             OPR52X1:                             $B=(B(A)); A1=B-FIELD                 22230000 D
0781  4009 A012 0000 C0F0           A1 EOL 0                      $A3=JUMP ADDR;MAR1=ADDR OF B(A)       22240000 D
0782  6400 0C42 0000 00F0           IF FALSE THEN NOT B;STEP ELSE SKIP                                  22250000 D
0783  67D9 0C40 4000 C0F0           IF NOT ABT THEN B=A1;SET LC1;SKIP  $NO JUMP IF B(A)=C               22260000 D
0784  0A50 0000 0000 C040           IFETCH-1=MPCR                                                       22270000 D
0785  4009 A0DE 0000 00F0           A1-1=MIR                      $DECREMENT B(A) AND JUMP              22280000 D
0786  2300 0000 0000 0060           OUTPUT1-1=CPCR                                                      22290000 D
0787  266C 0000 0000 0040           PUTJUMP-1=MPCR                                                      22300000 D
                             $ **********************      JUMP SY+B        ********************        22310000 D
                             OPR52X2:                             $MIR=B-FIELD                          22320000 D
0788  4009 A001 1000 00F0           A1 L=A3,BMI                   $JUMP TO SY+B                         22330000 D
0789  0000 0000 000C 00A0           16=SAR;BBASE=LIT              $ISOLATE SY-FIELD                     22340000 D
078A  4009 2C40 003C 00F0           LIT+B=MAR                     $MAR=ADDR OF B-REG                    22350000 D
078B  A009 E0C0 9000 00F0           A3 R=A3;MR1;IF RDC                                                  22360000 D
078C  AC08 0000 0C00 00F0           WHEN RDC THEN BEX             $B=(B)                                22370000 D
078D  49C9 EC40 1000 00F0           A3+B=A3;SET LC1               $A3=SY+B(B)                           22380000 D
078E  2660 0000 0000 0040           PUTJUMP-1=MPCR                                                      22390000 D
                             $ **********************      UNCONDITIONAL JUMP LOWER **************      22400000 C
                             OPR52X3:                             $A3=JUMP ADDRESS                      22410000 D
078F  4009 E003 0C1C 00F0           A3=MAR2                                                             22420000 D
0790  A009 C000 A000 4CF0           A2 R=A2,CSAR;MR2;IF RDC       $DELETE OLD PAR;READ JUMP ADDRESS     22430000 D
0791  03F0 0000 0000 00A0           20=SAR;63=LIT                 $LOWER WORD BIT 15 = LSB IS SET       22440000 D
0792  AC08 C000 2C00 00F0           WHEN RDC THEN A2 OR B001 L=A2,BEX                                   22450000 D
0793  4009 0C41 C000 00F0           B C=A1                        $LOWER WORD SHIFTED TO UPPER          22460000 D
0794  2000 0000 0000 0010           10=SAR                        $SETUP OPCODE TO BE EXECUTED          22470000 D
0795  4009 A156 0C00 C0F0           A1 AND LIT=AMPCR              $OPCODE IN AMPCR                      22480000 D
0796  4009 0C41 CC00 00FC           B C=A1                        $SWAP LOWER WORD TO UPPER             22490000 C
0797  0000 0000 000C 0020           16=SAR                                                              22500000 D
0798  4024 CF5C 2C00 C0F0           A2 OR BMAR=A2;EXEC            $INSERT NEW PAR                       22510000 D
0799  402D C0C0 2000 00F0           A2+1=A2;JUMP                                                        22520000 D
                             $ **********************      JUMP OVERFLOW AND A      *************       22530000 D
                             OPR53X0:                             $B=A-FILED;A3=JUMP ADDRESS            22540000 D
079A  4009 0C52 0000 00F0           0 EOL B                                                             22550000 D
079B  63C9 C0C1 A000 40F0           A2 C = A2,CSAR; IF FALSE THEN SET LC1                               22560000 D
079C  900C 0000 0000 0030           COMP 3=SAR                                                          22570000 D
079D  266C 0000 000C 00C0           PUTJUMP-1 = AMPCR                                                   22580000 D
079E  4009 C000 0000 00F0           A2                                                                  22590000 D
079F  4019 000F A000 C0F0           A2 AND B011 C = A2; IF MST THEN SKIP                                22600000 D
07A0  23ED 00C0 0000 C0F0           IF NOT LC1 THEN SET LC1;JUMP ELSE JUMP                              22610000 D
07A1  2BED 0000 0000 00F0           IF LC1 THEN SET LC1;JUMP ELSE JUMP                                  22620000 D
                                    $JUMP IF A=0 AND NO OVERFLOW OR A=1 AND OVERFLOW                    22630000 D
                             $ **********************      JUMP ON CD EQUAL/UNEQUAL/LIMITS      ****  22640000 D
                             OPR53X1:                             $B= A-FILED; A3=JUMP ADDRESS          22650000 D
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07A2  4809 0C40 4000 C0F0          B = A1                                                    22660C00 D
07A3  4809 A640 0040 00F0          A1+AMPCR=AMPCR              $OPCODE IN A1                 22670C0C D
07A4  3AD0 0000 0C0C C0C0          ACD-1=AMPCR                                               22680000 D
07A5  4809 00C0 0000 00F0          STEP                        $ ALLOW AMPCR TO SET          22690C00 D
07A6  4824 C0C1 9000 00F0          A2 C=A3;EXEC                $MSB=GE;LSB=EQL;2ND MSB=LIMITS BIT 22700C00 D
07A7  3000 0000 0000 C030          31 = SAR                                                  22710000 D
07A8  4836 E000 0000 00FC          A3;CALL                                                   2272CC00 D
07A9  49D8 0F40 1000 C0F0          BMAR = A3; SET LC1; SKIP    $ RETURN HERE IF LEGAL JUMP   2273C000 D
07AA  0A50 0000 0030 0040          IFETCH-1=MPCR                                             2274CC00 D
07AB  2660 0000 0000 0040          PUTJUMP-1=MPCR                                            22750C00 D
                                $ ************************      RETURN JUMP      ********************* 22760C00 D
                                0PR53X2:                        $JUMP ADDRESS IN A3;B=A-FIELD 2277C000 D
07AC  4809 0C40 4030 00F0          B=SAR,A1,LMAR               $A1=A-FIELD; MAR=SWITCHES     22780C00 D
07AD  0580 0000 0050 00E0          SWITCH =LIT                                               22790C00 D
07AE  A009 A15E 0030 00F0          A1 GEQ LIT;MR1;IF RDC                                     22800C00 D
07AF  0040 00C0 0000 00E0          4=LIT                       $A=4 THEN STOP                22810C00 D
07B0  78C9 0000 0005 00F0          0=CTR; IF TRUE THEN SET LC1                               22820C00 D
07B1  AC08 A002 0C00 00F0          WHEN RDC THEN NOT A1,BEX    $B=SWITCHES                   22830C00 D
07B2  68C9 0000 0C00 00F0          IF ABT THEN SET LC1         $A=0 THEN JUMP                22840C00 D
07B3  4809 0C40 8800 00F0          B R=B                       $CHECK PROPER BIT             22850C00 D
07B4  4809 0C40 0030 00F0          B                                                         2286CC00 D
07B5  58C9 0000 0000 00F0          IF LST THEN SET LC1         $SWITCH SET => JUMP           22870000 D
07B6  2FD9 A15E 0000 00F0          IF LC1 THEN A1 GEQ LIT;SET LC1;SKIP                       2280C000 D
07B7  0A50 0000 0030 0040          IFETCH-1=MPCR                                             2289C000 D
07B8  7801 0000 0000 C0F0          IF TRUE THEN WAIT                                         22900000 D
07B9  4809 C001 9008 40F0          A2 L=A1,LMAR,CSAR           $SAVE THE PAR IN A1           22910000 D
07BA  8100 0000 0000 00A0          SBASE=LIT;COMP 12=SAR                                     22920C00 D
07BB  4812 A008 C090 00F0          A1 R=A1,MIR;SAVE            $A1=0/PAR=>S&Y                22930C00 D
07BC  A809 0000 0050 08F0          MR1;IF RDC                  $READ BASE REG :X:            22940000 D
07BD  AC08 0000 0C0C 00F0          WHEN RDC THEN BEX           $$FORM A+Y-(S) AND CHECK SIGN  22950000 D
07BE  4809 AC5E 0050 00F0          A1-B=MIR,BMI                $MIR =CURRENT DIFF.;B=PREV DIFF. 22960C00 D
07BF  4429 0F46 009E C0F0          IF NOT MST THEN BMAR+1=MAR,INC;JUMP                       22970C00 D
07C0  4809 E003 001C 00F0          A3=MAR2                     $ADDRESS OF NEXT INST.        22980000 D
07C1  A809 6009 C090 0CF0          CTR R=A1;MR2;IF RDC         $A1=S/0                       22990C00 D
07C2  3000 0000 0C00 0010          11=SAR                                                    23000C00 D
07C3  AC08 AC5D 9C00 00F0          WHEN RDC THEN A1 OR B L=A1,BEX                            23010C00 D
07C4  0000 0000 0050 0020          COMP 16=SAR                                               23020C00 D
07C5  4809 0C40 8830 00F0          B R=B                       $B=0/OPC,A,F,B                23030C00 D
07C6  4809 AC5D 8080 00F0          A1 OR B C=MIR               $OPC,A,F,B,S,Y                23040C00 D
07C7  4809 E0C0 1000 00F0          A3 + 1=A3                   $A3=JUMP ADDRESS+1            23050C00 D
07C8  2660 0000 0030 00C0          PUTJUMP-1=AMPCR                                           23060C00 D
07C9  9809 0000 000C 1CF0          MW2;IF SAI                                                23070C0C D
07CA  9C28 0000 0000 00F0          WHEN SAI THEN 0;JUMP                                      2308CC0C D
                                $ ************************      MANUAL JUMP      ********************* 2309CC0C D
                                0PR53X3:                        $B=A-FIELD;A3=JUMP ADDRESS    23100000 D
07CB  4809 0C40 4038 00FC          B=SAR,A1,LMAR               $SAR=A-FIELD                  23110C00 D
07CC  0580 0000 0000 00E0          SWITCH =LIT                                               23120C00 D
07CD  A809 A15E 0050 00F0          A1 GEQ LIT;MR1;IF RDC                                     23130C00 D
07CE  0040 0000 0030 00E0          4=LIT                                                     2314CC00 D
07CF  78C1 A002 0000 00F0          NOT A1; IF TRUE THEN WAIT;SET LC1                         23150C00 D
07D0  68C9 0000 0030 00F0          IF ABT THEN  SET LC1        $LC1=>A EQL 0                 23160C00 D
07D1  AC08 00C0 0C90 00F0          WHEN RDC THEN BEX                                         2317CC00 D
07D2  4809 0C40 8800 00F0          B R=B                       $B=SWITCH BIT IN LSB          23180000 D
07D3  4809 0C40 0030 00F0          B                                                         2319CC0C D
07D4  58C9 0000 0000 00F0          IF LST THEN SET LC1                                       23200C00 D
07D5  2BD9 0000 0000 C0F0          IF LC1 THEN SET LC1;SKIP                                  23210C0C D
07D6  0A50 0000 0030 0040          IFETCH-1=MPCR                                             23220000 D
07D7  2660 00C0 0000 0040          PUTJUMP-1=MPCR                                            23230C00 D
                                $ ************************     SCALE FACTOR      ************23240C0C D
                                0PR70X0:                                                    23250C00 D
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07D8  2250 0008 0090 0040          UNWRITTEN4-1=MPCR          $PRINT ERROR & RETURN TO HALFFETCH   23260C00 D
                                $ ************************   DOUBLE SCALE FACTOR          ************23270C00 D
                                0PR70X1:                                                            23280C00 D
07D9  225C 0008 0090 0040          UNWRITTEN4-1=MPCR          $PRINT ERROR & RETURN TO HALFFETCH   23290C00 D
                                $ ************************   COMPLEMENT A                 ************23300C00 D
                                0PR70X2:                                                            23310000 D
07DA  4809 0C42 0090 00F0          NOT B=MIR                                                        23320C00 D
07DB  08BC 0008 0000 0040          HALFFETCH-1=MPCR                                                 23330000 D
                                $ ************************   DOUBLE COMPLEMENT A          ************23340C00 D
                                0PR70X3:    $B=(A);MAR=A-ADDRESS                                    23350C00 D
07DC  4809 0C42 0090 00F0          NOT B=MIR                  $COMPLEMENT A                         23360000 D
07DD  9809 0008 0090 18F0          MW1; IF SAI                                                      23370C00 D
07DE  9C08 0F46 008C 00F0          WHEN SAI THEN BMAR+1=MAR                                         23380C00 D
07DF  4809 2F56 008C 00F0          LIT AND BMAR=MAR                                                 23390000 D
07E0  A809 0008 0000 08F0          MR1;IF RDC                                                       23400000 D
07E1  AC08 0008 0C90 00F0          WHEN RDC THEN BEX                                                23410C00 D
07E2  4809 0C42 0090 00F0          NOT B=MIR                  $COMPLEMENT A+1                       23420C00 D
07E3  08B0 0008 0090 0040          HALFFETCH-1=MPCR                                                 23430C00 D
                                $ ************************   MULTIPLY REGISTERS A X A+1   **********23440C00 D
                                0PR74X0:   $B=A-FIELD;A3=B-FIELD                                    23450C00 D
07E4  227C 0008 0090 C060          PUTPAR-1=CPCR              $SAVE A2                              23460C00 D
07E5  4809 E0C8 008C 00F0          A3=MAR                                                           23470C00 D
07E6  A809 A008 0090 08F0          A1=MIR;MR1;IF RDC          $READ A(B);CURRENT INSTR. IN MIR      23480C00 D
07E7  AC08 0C48 0C8C 00F0          WHEN RDC THEN B=MAR,BEX    $B=(A(B));MAR=A                       23490C00 D
07E8  A809 0C48 2000 08F0          B=A2;MR1;IF RDC            $A2=MULTIPLIER                        23500C00 D
07E9  AC08 0C08 0C90 C0F0          WHEN RDC THEN BEX          $B=MULTIPLICAND                       23510000 D
07EA  2980 0008 0090 0060          MULTIPLY-1=CPCR                                                  23520000 D
07EB  4809 E008 0D90 00F0          A3=MIR,BMI                 $OUTPUT LEAST;SAVE OLD A2             23530C00 D
07EC  9809 0008 0090 18F0          MW1;IF SAI                                                       23540C00 D
07ED  9C08 A008 0090 00F0          WHEN SAI THEN A1=MIR                                             23550000 D
07EE  4809 0F46 008C 00F0          BMAR+1=MAR                 $OUTPUT MOST                          23560000 D
07EF  4809 2F56 008C 00F0          LIT AND BMAR=MAR           $CONVERT A(B) TO A(0)                 23570C00 D
07F0  9809 0C48 4000 18F0          B=A1;MW1;IF SAI            $RESET INSTRUCTION IN A1              23580C00 D
07F1  08C0 0008 0000 00C0          HALFFETCH=AMPCR            $PREPAR EXIT TO HALFFETCH +1          23590C00 D
07F2  9C08 0008 0090 00F0          WHEN SAI THEN 0;STEP                                             23600000 D
07F3  22A0 0008 0090 0040          GETPAR-1=MPCR              $RESTORE A2;RETURN TO HALFFETCH       23610C00 D
                                $ ************************ DIVIDE A(A+1),A(A) / A(B) => A(A)         23620000 D
                                0PR74X1:   $B=A-FIELD; A3=B-FIELD                                   23630C00 D
07F4  2270 0008 0090 0060          PUTPAR-1=CPCR              $SAVE A2                              23640C00 D
07F5  4809 0C46 008C 00F0          B+1=MAR                    $READ A+1                             23650C00 D
07F6  4809 2F56 008C C0F0          LIT AND BMAR=MAR           $CONVERT A(B) TO A(0)                 23660C00 D
07F7  0070 0008 0000 00E0          7=LIT                                                            23670C00 D
07F8  A809 A008 0090 08F0          A1=MIR;MR1;IF RDC          $SAVE A1                              23680C00 D
07F9  4809 0C40 2000 C0F0          B=A2                       $SAVE A-ADDRESS                       23690C00 D
07FA  AC08 E008 0C8C 00F0          WHEN RDC THEN A3=MAR,BEX                                         23700C00 D
07FB  A809 0C40 1000 C8F0          B=A3;MR1;IF RDC                                                  23710000 D
07FC  AC08 C008 0C8C 00F0          WHEN RDC THEN A2=MAR,BEX   $A-ADDRESS IN MAR                     23720C00 D
07FD  2A80 00C8 0090 0060          DIVIDE-1=CPCR              $A3=MOST DIVIDEND;B=DIVISOR           23730000 D
07FE  4809 C0C8 0D90 00F0          A2=MIR,BMI                 $A2=QUOTIENT;A1=REMAINDER             23740C00 D
07FF  6C09 00C8 009C 00F0          IF ABT THEN C=MIR                                                23750000 D
0800  9809 0008 0090 18F0          MW1;IF SAI                                                       23760C00 D
0801  9C08 0F46 008C 00F0          WHEN SAI THEN BMAR+1=MAR                                         23770C00 D
0802  4809 2F56 008C 00F0          LIT AND BMAR=MAR           $CONVERT A(B) TO A(0)                 23780C00 D
0803  0070 00C8 0000 00E0          7=LIT                                                            23790C00 D
0804  4809 A0C8 0090 C0F0          A1=MIR                                                           23800000 D
0805  6C09 0008 0090 C0F0          IF ABT THEN 0=MIR                                                23810C00 D
0806  9809 0C40 4000 18F0          B=A1; MW1; IF SAI          $RESET INSTRUCTION IN A1              23820C00 D
0807  9C08 0008 0000 00F0          WHEN SAI THEN 0;STEP                                             23830C00 D
0808  22A0 0008 0090 C060          GETPAR-1=CPCR                                                    23840000 D
0809  4809 C0C1 A000 40F0          A2 C=A2,CSAR                                                     23850C00 D
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080A 9000 0000 0000 0030          COMP 3=SAR                                                        23060000 D
080B 2C19 D01D A000 00F0          IF LC1 THEN A2 OR B100 C=A2;SKIP                                  23070C00 D
080C 4009 D00F A000 00F0          A2 AND B011 C=A2              %CLEAR OVERFLOW                      23080C00 D
080D 0BC0 0000 0000 0040          HALFFETCH=MPCR                %ENTER HALFFETCH AT +1               23090C00 D
                       % ***********************     SQUARE ROOT                ************23900C00 D
                       OPR74X2:     % A3=B-FIELD; B=A-FIELD                                          23910C00 D
080E 2270 00C0 000P 0060          PUTPAR-1=CPCR                 %SAVE A2                             23920C00 D
080F 4009 A000 0008 00F0          A1=MIR,LMAR                   %SAVE CURRENT INSTRUCTION            23930C00 D
0810 019C 0000 0000 00B0          CINST=LIT;COMP 8=SAR                                               23940C00 D
0811 9009 E001 0010 10F0          A3 L=BR2;MW1;IF SAI           %SAVE B-FIELD IN BR2                 23950C00 D
0812 9C08 0C46 000C C0F0          WHEN SAI THEN B+1=MAR         %SETUP FOR A+1                       23960C00 D
0813 4009 2F56 000C 00F0          BMAR AND LIT=MAR              %CONVERT A(B) TO A(0)                23970C00 D
0814 0070 0000 0030 00E0          7=LIT                                                              2398CC00 D
0815 A009 0000 0000 C0F0          MR1;IF RDC                    %READ A+1                            2399CC00 D
0816 AC08 0C40 0C0C 00F0          WHEN RDC THEN B=MAR,BEX       %B=(A+1);MAR=A                       24000C00 D
0817 A009 0C40 0000 00FC          B;MR1;IF RDC                  %READ A                              24010C00 D
0818 4E4B 00C6 0000 00F0          IF MST THEN B001+1=B;SET LC2;STEP ELSE SKIP                        24020000 D
0819 2130 0000 0000 0040          ERRORMSG-1=MPCR               %SQUARE ROOT OF NEGATIVE             24030C00 D
081A 4009 0C40 4001 00F0          B=A1,LCTR                                                          24040000 D
081B A0F0 0000 0030 00B0          15=LIT;COMP 2=SAR             %A1=(A+1)                            24050C00 D
081C 4052 0000 3B30 00F0          0=A3,A2,B,MIR;SET LC2;SAVE %INITIALIZE REGISTERS                   24060C00 D
081D 4009 A000 0B02 C0F0  SORT1:  A1 R=B,INC                                                         2407CC00 D
081E 4009 CC5C 2000 00F0          A2 OR B=A2,BMI                %OR 2 MS BITS INTO A2                2408CC00 D
081F 4009 C012 0000 00F0          A2 EOL 0                                                           24090C00 D
0820 6419 CC58 0000 00F0          IF FALSE THEN A2 GTR B;SKIP                                        24100C00 D
0821 0F80 0000 0C00 0040          SORT2-1=MPCR                                                       24110C00 D
0822 7C19 0C46 0000 C0FC          IF TRUE THEN B+1=B;SKIP                                            2412000C D
0823 0F90 0000 0030 0040          SORT2-1=MPCR                                                       24130C00 D
0824 4009 CC5E 2000 00F0          A2-B=A2                                                            2414CC00 D
0825 4009 E0DC 1000 00F0          A3 OR B001=A3                                                      24150C00 D
0826 8419 0C40 0000 C0F0  SORT2:  IF NOT COV THEN B;SKIP                                             2416CC00 D
0827 0FA0 0000 0000 0040          SORT3-1=MPCR                                                       24170C00 D
0828 5C09 0C46 0000 00F0          IF LST THEN B+1=B                                                  24180000 D
0829 4009 0C41 0000 00F0          B L=MIR                       %DOUBLE B                            24190000 D
082A B000 0000 0C00 0030          COMP 1=SAR                                                         24200C00 D
082B 4009 EDCA 1000 00F0          A3 OAD 0=A3                                                        24210C00 D
082C 4009 A0C1 4000 00F0          A1 L=A1                                                            2422CC00 D
082D A000 0000 0000 0030          COMP 2=SAR                                                         24230C00 C
082E 4020 C001 2000 00F0          A2 L=A2;JUMP                                                       24240C00 D
082F 3C19 E00A 1000 00F0  SORT3:  IF LC2 THEN A3 OAD 0=A3;SKIP                                       2425CC00 D
0830 0FB0 0000 0000 004C          SORT4-1=MPCR                  %A3=ANSWER;A2=RESIDUE                24260C00 D
0831 AC08 C0C1 2C01 00F0          WHEN RDC THEN A2 L=A2,BEX,LCTR                                     2427CC00 D
0832 402D 0C40 4000 24F0          B=A1;ASE;JUMP                 %SELECT BR2                          24280C00 D
0833 4009 E000 0C30 24FC  SORT4:  A3=MIR;ASE                    %SELECT BR2                          24290C00 D
0834 4009 0F40 000C 00F0          BMAR R=MAR                    %SETUP FOR A(B)                      2430CC00 D
0835 007C 0000 0000 0090          8=SAR;7=LIT                                                        24310000 D
0836 9009 0000 0000 10F0          MW1;IF SAI                    %OUTPUT ANSWER                       24320C00 D
0837 9C08 0F46 000C 00F0          WHEN SAI THEN BMAR+1=MAR                                           24330C00 D
0838 4009 2F56 000C C0F0          BMAR AND LIT=MAR              %CONVERT A(B) TO A(0)                24340C00 D
0839 4009 C000 0050 C0F0          A2 = MIR                                                           2435OC0C D
083A 9009 0000 0000 10F0          MW1;IF SAI                    %OUTPUT RESIDUE                      24360C0C D
083B 9C08 0000 0000 00F0          WHEN SAI THEN 0;STEP                                               24370C00 D
083C 22A0 0000 0030 0060          GETPAR-1=CPCR                 %RESTORE A2 TO PAR'                  24380C00 D
083D 4009 0000 0008 00F0          LMAR                          %FETCH CURRENT INSTRUCTION           24390C00 D
083E 0190 0000 0030 00EC          CINST=LIT                                                          24400000 D
083F A009 0000 0000 00F0          MR1;IF RDC                                                         24410000 D
0840 AC08 00C0 0C00 00F0          WHEN RDC THEN BEX                                                  24420C00 D
0841 4009 0C40 4000 C0F0          B=A1                          %RESTORE A1 TO CURRENT INSTRUCTION   24430000 D
0842 0BC0 0000 0000 0040          HALFFETCH=MPCR                %ENTER HALFFETCH AT +1               24440000 D
                       % ***********************    LOAD B(A) WITH B(B)       ************** 24450C00 D
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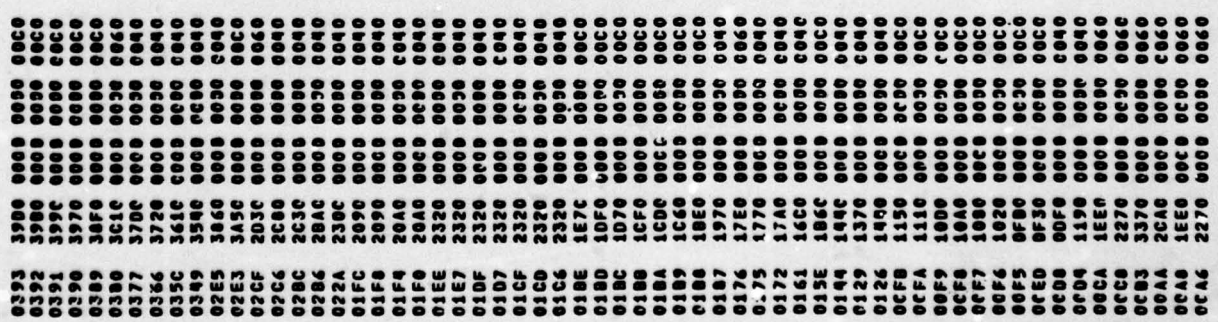
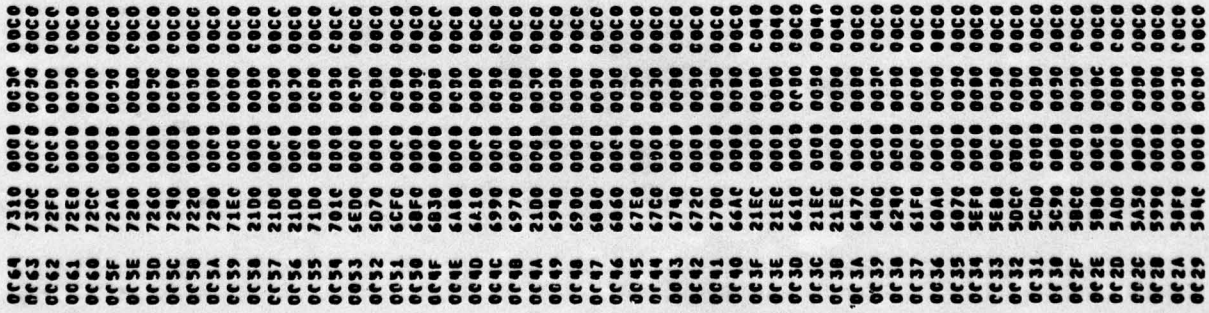
                                OPR74X3:    $MIR=A-FIELD; A3=B-FIELD                                    24460C00 D
0843  4809 E140 009C 00F0            A3+LIT=MAR                  $MAR=B(B)                             24470C00 D
0844  0080 0000 0090 00E0            BBASE=LIT                                                         24480C00 D
0845  A809 0000 0000 00F0            MR1;IF RDC                                                        24490C00 D
0846  AC08 0000 0C90 00F0            WHEN RDC THEN BEX           $READ B(B)                            24500C00 D
0847  4809 0C40 0090 00F0            B=MIR,BMI                                                         24510C00 D
0848  4809 0C52 0000 00F0            0 EQL B                     $CHECK FOR B(0) => ILLEGAL            24520C00 D
0849  6408 2C40 009C 00F0            IF FALSE THEN LIT + B=MAR;STEP ELSE SKIP                          24530C00 D
084A  0080 0000 0000 0040            HALFFETCH-1=MPCR            $MAR=B(A) ADDRESS                     24540C00 D
084B  00C0 0000 0090 0040            HALFFETCH=MPCR              $ENTER AT +1 AND DO NOT WRITE B(0)    24550C00 D
                                $ ********************     COMPARE REGISTERS    ********************  24560C0C D
                                OPR74X4:     $A3=A(B); B=A(A)                                         24570000 D
084C  4809 E000 009C 00F0            A3=MAR                      $READ A(B)                            24580C00 D
084D  A809 0000 0090 00F0            MR1;IF RDC                                                        24590C00 D
084E  AC08 0000 0C90 00F0            WHEN RDC THEN BEX                                                 24600C00 D
084F  4809 0C40 1D90 00F0            B=A3,BMI                    $A3=(A(B))                            24610C00 D
0850  4809 0C40 009C 00F0            B=MAR                       $MAR = ADDRESS OF A(A)                24620C00 D
0851  A809 0000 0000 00F0            MR1;IF RDC                                                        24630C00 D
0852  AC08 0000 0C90 00F0            WHEN RDC THEN BEX           $A3=A(B);B=A(A)                       24640C00 D
0853  2060 0000 0090 0040            SETCOMPARE-1=MPCR                                                 24650C00 D
                                $ ********************   COMPARE A(B) WITH A(A+1); A(A) SET CD*****     24660C00 D
                                OPR74X5:    $B,MIR=A-FIELD; A3=B-FIELD                                24670000 D
0854  4809 0C40 008C 20F0            B=MAR;ASR                   $SETUP FOR BMAR1                      24680C00 D
0855  00C0 0000 0090 00C0            HALFFETCH=AMPCR                                                   24690C00 D
0856  A809 0000 0000 00F0            MR1;IF RDC                                                        24700C00 D
0857  AC08 0F46 0C9C 00F0            WHEN RDC THEN BMAR+1=MAR,BEX                                      24710C00 D
0858  4809 2F56 009C 00F0            LIT AND BMAR=MAR            $CONVERT A(B) TO A(0)                 24720C00 D
0859  A809 0C40 0090 00F0            B=MIR;MR1;IF RDC            $MIR=(A(A))                           24730000 D
085A  AC08 E0C0 0C9C 00F0            WHEN RDC THEN A3=MAR,BEX    $B=(A(A+1))                           24740C00 D
085B  A809 0C40 1090 00F0            B=A3;MR1;IF RDC             $A3=(A(A+1))                          24750C00 D
085C  AC08 0000 0C90 00F0            WHEN RDC THEN BEX           $B=(A(B))                             24760C00 D
                                OPR74XX5: $MIR=A(A);A3=A(A+1);B=A(B)                                    24770C0C D
085D  4809 C001 A000 40F0            A2 C=A2,CSAR                $LIMITS BIT IS MSB                    24780000 D
085E  A000 0000 0090 0030            COMP 2=SAR                                                        24790C00 D
085F  4809 EC4C 0C90 00F0            A3 XOR B                    $TEST DIFFERENT SIGNS                 24800C00 D
0860  480B EC58 0000 C0F0            A3 LEQ B; IF MST THEN STEP ELSE SKIP                              24810C00 D
0861  7C2B D81D A000 C0F0            IF FALSE THEN A2 OR B100 C=A2;JUMP ELSE SKIP                      24820C00 C
0862  7429 D81D A000 00F0            IF TRUE THEN A2 OR B100 C=A2;JUMP  $SAME SIGNS                    24830C00 D
0863  4809 0C40 1D90 C0F0            B=A3,BMI                                                          24840000 D
0864  4809 EC4C 0000 00F0            A3 XOR B                    $A3=A(B);B=A(A)                       24850000 D
0865  480B EC5E 0000 00F0            A3 LSS B; IF MST THEN STEP ELSE SKIP                              24860000 D
0866  7C2B D81D A000 00F0            IF FALSE THEN A2 OR B100 C=A2;JUMP ELSE SKIP                      24870000 D
0867  7429 D81D A090 00F0            IF TRUE THEN A2 OR B100 C=A2;JUMP                                 24880C00 D
0868  482D D80F A000 C0F0            A2 AND B011 C=A2;JUMP                                             24890C00 D
                                $ ********************   COMPARE A(A+1) AND A(A) WITH A(B)   ******     24900C00 D
                                OPR74X6:    $B,MIR=A-FIELD; A3=B-FIELD                                24910C00 D
0869  4809 0C40 009C 20F0            B=MAR;ASR                   $SETUP FOR A(A); BMAR=MAR1            24920C00 D
086A  A809 0000 0000 00F0            MR1;IF RDC                                                        24930C0C D
086B  AC08 0F46 0C9C 00F0            WHEN RDC THEN BMAR+1=MAR,BEX                                      24940000 D
086C  4809 2F56 009C 00F0            LIT AND BMAR=MAR            $CONVERT A(B) TO A(0)                 24950C00 D
086D  A809 0C40 0090 C0F0            B=MIR;MR1;IF RDC            $B=(A(A))                             24960C00 D
086E  AC08 E000 0C9C 00F0            WHEN RDC THEN A3=MAR,BEX                                          24970C00 D
086F  A809 0C40 1D90 00F0            B=A3,BMI;MR1;IF RDC         $B=(A(A));A3=(A(A+1))                 24980000 D
0870  AC08 EC56 1C90 00F0            WHEN RDC THEN A3 AND B=A3,BEX                                     24990C00 D
0871  2060 0000 0000 034C            SETCOMPARE-1=MPCR           $A3=A(B)                              25000C00 D
                                $********************     COMPARE B(B) WITH B(A)   **************     25010000 D
                                OPR74X7:     $B,MIR=A-FIELD; A3=B-FIELD                               25020C00 D
0872  4809 2C40 009C C0F0            LIT+B=MAR                                                         25030C00 D
0873  0080 0000 0090 00E0            BBASE=LIT                                                         25040C00 D
0874  A809 0000 0000 C0F0            MR1;IF RDC                  $READ B(A)                            25050C00 D
```

```
0875  AC08 E140 0C0C C0F0          WHEN RDC THEN A3+LIT=MAR,BEX                                    25060C00 D
0876  A009 0C40 0090 08F0          B=MIR;MR1;IF RDC                                                25070C00 D
0877  AC08 0008 0C00 00F0          WHEN RDC THEN BEX                                               25080C00 D
0878  4809 0C48 1D90 00F0          B=A3,BMI                  $B=B(A);A3=B(B)                       25090C00 D
0879  2060 0008 0090 0040          SETCOMPARE-1=MPCR         $B=B(B);A3=B(A)                       25100C00 D
                                 $ ************************  STORE IOC MONITOR CLOCK  ************25110C00 D
                                 OPR77X0:                                                        25120C00 D
087A  2250 0008 0090 0040          UNWRITTEN4-1=MPCR         $PRINT ERROR & RETURN TO HALFFETCH    25130C00 D
                                 $ ************************  STORE REAL-TIME CLOCK    ************25140C00 D
                                 OPR77X1:                                                        25150C00 D
087B  2250 0008 0090 0040          UNWRITTEN4-1=MPCR         $PRINT ERROR & RETURN TO HALFFETCH    25160C00 D
                                 $ ************************  PREVENT CLASS 3 INTERRUPT ************25170C00 D
                                 OPR77X4:                                                        25180C00 D
087C  2250 0008 0090 0040          UNWRITTEN4-1=MPCR         $PRINT ERROR & RETURN TO HALFFETCH    25190C00 D
                                 $ ************************  ALLOW CLASS 3 INTERRUPT  ************25200C00 D
                                 OPR77X5:                                                        25210C00 D
087D  2250 0008 0090 0040          UNWRITTEN4-1=MPCR         $PRINT ERROR & RETURN TO HALFFETCH    25220C00 D
                                 $ ************************  STOP PROCESSOR/WAIT INT. ************25230C00 D
                                 OPR77X6:                                                        25240C00 D
087E  4800 0008 0090 00F0          WAIT                                                            25250C00 D
087F  4809 0818 001C 00F0          0111=MAR2                 $WRITE TO MAILBOX                     25260C00 D
0880  4809 2001 0090 00F0          LIT L=MIR                 $SIGNALS LOADER TO RESTART            25270C00 D
0881  0000 0008 0090 00A0          0=LIT;16=SAR                                                    25280C00 D
0882  3809 0008 0090 1CF0          MV2;IF SAI                                                      25290C00 D
0883  9F58 0008 0001 C0F0          WHEN SAI THEN RESET GC1;LCTR %GIVE GC1 TO LOADER                253C0C00 D
0884  0640 0008 0C90 00E0          100=LIT                   $WASTE TIME                           25310C00 D
0885  0800 0008 0002 00F0          INC; WHEN COV THEN STEP                                         25320C00 D
0886  0A00 0008 0090 0040          START=MPCR                $RESTART PROGRAM                      25330C00 D
0887  0000 0008 0090 0040          END                                                             25340C00 D
0830  032C 0008 009C 0040       ?END
0827  02E0 0008 0090 0040
0823  0250 0008 0090 0040
0821  0250 00C0 0090 0040
0713  7100 0008 0090 0040
06CB  6CDC 0008 0090 0040
064A  658C 0008 0090 00C0
062A  6340 0008 0090 0040
0610  610C 0008 009C 0040
05FB  6000 0008 0090 0040
0570  95C0 0008 0090 0040
04C2  9C80 0008 0090 0040
0476  5100 00C0 0090 0040
0446  6C70 0008 0090 0040
03D6  91C0 0008 0090 00C0
03CE  3D40 0008 0090 00C0
03CA  3CD0 0008 0090 00C0
03C5  3DC0 0008 0090 00C0
03B5  3BF0 00C0 0090 00C0
03B4  3B00 0008 0090 00CC
03B3  3B80 0008 0090 00C0
03B2  3BA0 0008 0090 00C0
03B1  3B90 0008 0090 00C0
03B0  3B7C 0008 0090 00C0
03AF  3B60 0008 0090 00C0
03AE  3B5C 0008 009C 00C0
03A7  3AD0 0008 0090 00C0
0397  3A40 0008 0090 00C0
0396  3A20 00C0 0090 00C0
0395  3A00 0008 0090 00C0
0394  39F0 0008 0090 00C0
```



```
0CA2  22A0 0000 0000 0060
0C9F  21E0 0000 0000 0040
0C9E  87D0 00C0 0000 00C0
0C9D  87C0 0000 0C00 00C0
0C9C  8780 0CC0 0000 00C0
0C9B  21E0 0000 0C00 C040
0C9A  21E0 0000 0000 0040
0C99  87A0 0000 0000 00C0
0C98  8790 0000 0000 00C0
0C97  871C 0000 0000 00C0
0C96  868C 0000 0000 00C0
0C95  8530 0000 0000 C0C0
0C94  84B0 0000 0000 C0C0
0C93  8420 0000 0000 00C0
0C92  80D0 00C0 000C 00C0
0C91  7F30 0000 0000 C0C0
0C90  7E30 0000 0000 00C0
0C8F  21E0 00C0 0000 0040
0C8E  21E0 0000 0000 0040
0C8D  21E0 0000 0000 0040
0C8C  21E0 0000 0C00 0040
0C8B  7D80 0000 0000 C0CC
0C8A  7D90 0000 0000 00C0
0C89  7D80 00C0 000C 00C0
0C88  7D70 0000 0C00 00C0
0C87  21D0 0000 0000 00C0
0C86  21D0 0000 0000 00C0
0C85  21D0 0000 0000 00C0
0C84  7CA0 0000 0000 00C0
0C83  7AB0 0000 0C00 00C0
0C82  7A10 0000 0000 00C0
0C81  7990 0000 0000 00C0
0C80  21D0 0000 0000 C0C0
0C7F  21D0 0000 000C 00C0
0C7E  21D0 0000 0000 00C0
0C7D  21D0 0000 0000 C0CC
0C7C  78EC 0000 0000 00C0
0C7B  7870 00C0 0000 00C0
0C7A  7800 0000 0000 00C0
0C79  77B0 0000 0000 00C0
0C78  21D0 00C0 0000 00C0
0C77  21D0 0000 0C00 00C0
0C76  21D0 0000 0000 00C0
0C75  21D0 0000 0000 00C0
0C74  7780 0000 0C00 C0C0
0C73  7750 0000 000C 00C0
0C72  7730 0000 0000 00C0
0C71  7700 0000 0C00 C0C0
0C70  21DC 0000 0000 C0C0
0C6F  21DC 0000 0000 00CC
0C6E  21DC 0000 0000 00C0
0C6D  21DC 0000 0000 00C0
0C6C  76E0 0000 0000 00C0
0C6B  7630 0000 0000 C0C0
0C6A  7610 0000 0000 00C0
0C69  7560 0000 0C00 00C0
0C68  21D0 0000 0000 00C0
0C67  73AC 0000 0C00 00C0
0C66  7390 0000 0000 00C0
0C65  7320 0000 0000 C0C0
```



```
0028  5790 0008 0090 00C0
0027  5700 0008 0090 00C0
0026  5650 0008 0090 00C0
0025  55EC 00C8 0090 00C0
0024  5480 0008 0090 00C0
0023  5410 0008 009C 00CC
0022  5270 0008 0090 00C0
0021  519C 0008 009C 00C0
0020  5130 000C 0090 00C0
001F  50E0 00C8 0090 00C0
001E  5070 00C0 0090 00C0
001D  4FDC 0008 0090 00C0
001C  4F80 0008 009C 00C0
001B  4F10 00C8 0090 00C0
001A  2100 00C8 0090 00C0
0019  210C 00C0 000C 00C0
0018  4EA0 0008 00D0 00C0
0017  4E50 0008 009C 00C0
0016  4CF0 0008 0090 00C0
0015  4CA0 0008 0090 00C0
0014  4B0C 0008 0090 00C0
0013  4B00 0008 0090 00C0
0012  4A30 0008 0090 00C0
0011  490C 0008 0090 00C0
0010  4960 0008 0090 00C0
000F  4920 0008 009C 00C0
000E  487C 0008 0090 00C0
000D  47F0 0008 0090 00C0
000C  4770 0008 0090 00C0
000B  4680 0008 0090 00C0
000A  45F0 0008 0090 00C0
0009  45C0 0008 0090 00C0
0008  4530 0008 0090 00C0
0007  452C 0008 0090 00C0
0006  44A0 00C8 0090 00C0
0005  210C 00C8 009C 00C0
0004  4480 00C0 0090 00C0
0003  4360 0008 0090 00C0
0002  42C0 0008 0090 00C0
0001  210C 0008 009C 00C0
0000  09F0 0008 009C 0040
 0 ERRORS    2536 CARDS.  14930 TOKENS.     26338 RULES.      1792 SECONDS.
 0 WARNINGS.      100 DISK SECTORS.
```

APPENDIX C. LOADER PROGRAM LISTING

This appendix provides a copy of the Microtranslator output listing of the Loader written in conjunction with the Emulator. Its source is maintained on disk and cards; and its object module is maintained on disk. The Loader actually consists of three separate programs which provide assembly, debugging and IOC functions to the Emulator. It is a by-product of the Emulation, and it was used for implementation and testing of the Emulator. Its functions should be incorporated in the Emulator Program in the course of expansion to a full emulation.

```
[OUT-32]      TRANSLANG ASSEMBLER   (02/24/76)          TUESDAY  09/28/76   15:35:37

                                    $MERGE LOADER-SOURCE
                                    PROGRAM UYK7-LOADER                                                    00010C00 D
                                          $                                                                00020000 D
                                    ABASE=0                        $ADDRESS OF A-REG(0)                    00030000 D
                                    BBASE=8                        $ADDRESS OF B-REG(0)                    00040C00 D
                                    SBASE=16                       $ADDRESS OF S-REG(C)                    00050C00 D
                                    PAR=29                         $ADDRESS OF P-REGISTER TEMP.            00060000 D
                                    SWITCH=80                      $LOCATIO( TO STORE SWITCH CHOICES       00070C00 D
                                    PLOC=120                       $TEMPORARY ADDR. OF NEXT INSTRUCTION    00080C00 D
                                    NEXADDR=210                    $ADDRESS TO INSERT ADDRESSES TO PRINT   00090C00 D
                                    CARDBUF=212                    $PERMANENT ADDR. OF CARDBUFFER          00100C00 D
                                    COL5X8=213                     $ADDRESS OF CARD COLS. K-8              00110000 D
                                    COL9X12=214                    $ADDRESS OF CARD COLS. 9-12             00120000 D
                                    COL13X16=215                   $ADDRESS OF CARD COLS. 13-16            00130C00 D
                                    LASTCOL=232                    $ADDRESS OF COL 80 OF CARD              00140C00 D
                                    PRINTADD=237                   $PERMANE(T LOCATION OF PRINT BUFFER     00150C00 D
                                          BLANKLINE=500            $LOACATION OF BUFFER OF SPACES          00160C00 D
                                          ERRORLIST=200. PRINTAREA=238. DISKADDR=3132                      00170000 D
                                          NUMLINES=36              $NUMBER OF LINES PRINTED X SIX          00180000 D
                                          $                                                                00190C00 D
                                          $BEGIN PROGRAM HERE BY ZEROING MEMORY                            00200C00 D
0C00  9800 0000 0030 00F0               WAIT                                                               00210C00 D
                                    START:  $RETURN HERE ON SIGNAL FROM EMULATOR TO RESTART                00220000 D
0C01  0088 00C1 401C 00F0               SET GC1; WHEN GC1 THEN 1 L=A1,MAR2                                 00230C00 D
0C02  0000 00C0 2030 0020               COMP 16 =: SAR                                                     00240C00 D
0C03  4812 0005 0030 00F0               0=: MIR; SAVE                                                      00250C00 D
0C04  9809 A0DE 4020 1CF0               MW2; A1-1 =: A1; IF SA1                                            00260C00 D
0C05  6819 0000 0C30 00F0               IF ABT THEN SKIP ELSE STEP              $DONE WHEN A1 TOGGLES TO   00270C00 D
0C06  9C28 A0C) 001C 00F0               WHEN SA1 THEN A1=: MAR2; JUMP                                      00280C00 D
                                          $                                                                00290C00 D
                                          $READ CARDS IN TO SETUP ERROR ROUTINES                           00300000 D
                                    ERRORSETUP:                                                            00310C00 D
0C07  4809 0009 001C 00F0               0110=MAR2                                                          00320000 D
0C08  4809 20C1 4030 00F0               LIT L=A1                                                           00330000 D
0C09  00C0 0000 0030 00B0               MOST(DISKADDR)=LIT; COMP 8=SAR                                     00340000 D
0C0A  4809 A15C 4030 00F0               A1 OR LIT=A1                                                       00350000 D
0C0B  03CC 0003 0030 00E0               LEAST(DISKADDR)=LIT                                                00360C00 D
0C0C  4809 2001 0B3C 00F0               LIT L=B                                                            00370C00 D
0C0D  0B4C 00C3 0030 00A0               COMP 16=SAR; 180=LIT        $READ FOUR SECTORS = 9 CARDS           00380C00 D
0C0E  4809 AC5C 0C30 00F0               A1 OR B=MIR                                                        00390C00 D
0C0F  000C 00C0 0030 004C               OUTPUT1-1=CPCR                                                     00400C00 D
0C10  4809 0640 4030 00F0               AMPCR=A1                                                           00410000 D
0C11  1180 0000 0030 00C0               ERRORLIST=AMPCR                                                    00420C00 D
0C12  4809 2001 0B30 00F0               LIT L=B                                                            00430C00 D
0C13  0030 0000 00B0 00A0               3=LIT;COMP 16=SAR                                                  00440C00 D
0C14  4809 AC5C 0C30 00F0               A1 OR B = MIR                                                      00450C00 D
                                    ERRORSETUP1:                                                           00460000 D
0C15  0010 0000 0030 0060               EXTOP-1=CPCR                                                       00470C00 D
0C16  014C 0000 0030 0040               ERRORSETUP1-1=MPCR                                                 00480C00 D
                                          $                                                                00490C00 D
                                          $SETUP BUFFER OF ALL SPACES FOR PRINTING BLANK LINES              00500000 D
0C17  4809 0000 0001 00F0               0=BCB,LCTR                                                         00510C00 D
0C18  0200 0000 0030 00E0               32=LIT                                                             00520C00 D
0C19  1F40 00C0 0000 00C0               BLANKLINE=AMPCR             $ADDRESS OF BUFFER                     00530000 D
0C1A  4809 0C40 0030 00F0               B=MIR                                                              00540000 D
0C1B  4809 0640 001C 00F0               AMPCR=MAR2                                                         00550C00 D
0C1C  4812 0000 0030 00F0               SAVE                                                               00560C00 D
0C1D  9809 0000 0030 1CF0               MW2; IF SA1                 $OUTPUT BLANKS = 30303030              00570000 D
```

```
0C1E  9C08 0F46 001E 00F0          WHEN SAI THEN BMAR+1=MAR2,INC                                    0058CC00 D
0C1F  0029 0000 0000 00F0          IF NOT COV THEN JUMP        %OUTPUT 33 BLANK WORDS               00590C00 D
0C20  2809 0008 1000 00F0          0=:A3;IF LC1             %INITIALIZE BASE REG TO 1C24            00600C00 D
0C21  0020 0000 0090 0040          LOADERADDRESS=:MPCR         %ENTER AT LOADER ADDRESS+1 TO INITIL 00610000 D
                                   %%CLEARS INPUT TO CARDS AND RETURNS HERE VIA NEWWRD              0062CC00 D
                                   %                                                                0063CC00 D
                                   %                                                                0064CC00 D
                                CHECKCOL1:                                                          0065CC00 D
0C22  4009 2008 009C 00F0          LIT=:MAR2,MIR                        %BUFFER ADDRESS IS 198      00660C00 D
0C23  0040 0008 0090 00E0          CARDBUF=LIT                                                      00670C00 D
0C24  0030 0000 0090 0060          INPUT-1=CPCR                                                     0068CC00 D
0C25  4009 2001 CC90 40F0          LIT C=A1,CSAR                                                    00690000 D
0C26  03F0 0008 0090 C090          63=:LIT;8=:SAR                                                   0070CC00 D
0C27  4009 AC56 8D2C 00F0          A1 AND B R =: B                      %CHAR IN B 0-7              00710C00 D
0C28  4009 2C52 0090 00F0          LIT EOL B                 %CHECK F3 "D"                          00720C00 D
0C29  0140 0000 0090 00E0          20=:LIT                                                          00730C00 D
0C2A  6419 2C52 0090 00F0          IF FALSE THEN LIT EOL B;SKIP    %CHECK FOR " "                   00740C00 D
0C2B  0040 0008 0090 0040          DATA-1=MPCR                                                      0075CC00 D
0C2C  030C 00C8 0090 00E0          48=:LIT                          %SPACE                          0076CC00 D
0C2D  6419 2C52 0C90 C0F0          IF FALSE THEN LIT EOL B;SKIP   %CHE"K FOR "I"                    0C77CC00 D
0C2E  0050 0008 0090 C04C          INSTRUCTION-1 =: MPCR                                            00780C00 D
0C2F  0190 0008 0090 00E0          25=:LIT                          %"I"                            00790C0C D
0C30  6419 2C52 0C90 00F0          IF FALSE THEN LIT EOL B;SKIP %CHECK FOR "B"                      008C0C00 D
0C31  006C 0008 0090 0040          SETINDEXREG-1 =: MPCR                                            0081CC00 D
0C32  026C 0008 0090 00E0          38=:LIT                          %"B"                            0082CC00 D
0C33  6419 2C52 0090 00F0          IF FALSE THEN LIT EOL B;SKIP %CHECK FOR "A"                      00830C00 D
0C34  007C 0008 0090 0040          ORIGIN-1 =: MPCR                                                 0084C000 D
0C35  0110 0008 0C90 00E0          17=:LIT                          %"A"                            0085CC00 D
0036  6419 2C52 0090 C0F0          IF FALSE THEN LIT EOL B;SKIP %CHECK FOR "S"                      00860C00 D
0037  0080 0008 0090 0040          SETAREG-1 =: MPCR                                                00870000 D
0038  0320 0008 0090 00E0          50=:LIT                          %"S"                            0088CC00 D
0039  6419 2C52 0C90 00F0          IF FALSE THEN LIT EOL B;SKIP  %CHEC5 FOR "N"                     0089CC00 D
003A  0090 0008 0C90 0040          SETSWITCHES-1 =: MPCR                                            0090CC00 D
003B  025C 0009 0090 C0E0          37=:LIT                          %"N"                            00910000 D
003C  6419 2C52 0090 00F0          IF FALSE THEN LIT EOL B;SKIP  %CHEC5 F0 "L"                      00920C00 D
003D  00A0 0008 003C 0040          IFETCH-1 =: MPCR                                                 0093CC00 D
003E  0230 0008 0090 00E0          35=:LIT          %"L"=ADDRESS TO LOAD TO                         00940C00 D
003F  6419 2C52 0C90 00F0          IF FALSE THEN LIT EOL B;SKIP  %CHEC5 FOR "Q"                     0095CC00 D
0040  008C 0008 9090 0040          LOADERADDRESS-1=:MPCR                                            0096C000 D
0041  0280 0008 0090 C0E0          40=:LIT                          %TEST FOR "Q"                   0097C000 D
0042  6419 2C52 0090 00F0          IF FALSE THEN LIT EOL B;SKIP  %CHECK FOR "R"                     0098CC00 D
0043  00C0 0008 0090 0040          DUMP-1=:MPCR                                                     0099CC00 D
0044  029C 0008 0090 00E0          41=LIT                           %"R" RESERVE AMOUNT OF SPACE IN 9-16 01000C00 D
0045  6419 2C52 0090 00F0          IF FALSE THEN LIT EOL B;SKIP  %CHCE"K FOR "W"                    01010C00 D
0046  000C 0008 0090 0040          RESERVE-1=MPCR                                                   0102CC00 D
0047  036C 0008 0090 00E0          54=LIT                           %"W" MEANS READ CHARACTER STRING 01030000 D
0048  6419 0008 1000 00F0          IF FALSE THEN 0=A3;SKIP                                          01040C00 D
0049  00EC 6008 0090 0040          WORD-1=MPCR                                                      01050000 D
004A  00F0 0008 0090 0040          PRINTER10-1=MPCR                                                 01060C00 D
                                   %                                                                01070C00 D
                                   %                                                                0108CC00 D
                                   %                                                                01090C00 D
                                INSTRUCTION:                                                       01100000 D
                                   %                                                                01110C00 D
                                   %OPCODE IS IN CARD COLS. 3-4                                     0112CC00 D
                                   %ANALYZE OPCODE AND DETERMINE TYPE OF FORMAT.                    01130C00 D
                                   %    IF OPC <=60 => FORMAT1                                      01140000 D
                                   %    IF 62<=OPC<=67 THEN FORMAT 4B                               01150C00 D
                                   %    ELSE FORMAT 4A                                              01160000 D
0C4B  4009 0003 1018 00F0          0=:A3,OR2,LMAR                   %FETCH WORD FROM 198            01170C00 D
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0C4C  0040 0000 0000 C0E0          CARDBUF=LIT                                          01180C00 D
0C4D  0100 0000 0C30 0060          READAFIELD-1=:CPCR                                   01190C00 D
0C4E  4009 2000 4000 C0F0          LIT=:A1                                              01200C00 D
0C4F  0070 0000 0000 00A0          7=LIT;COMP 16=SAR                                    01210C00 D
0C50  4012 0C41 0000 C0F0          B L=:B; SAVE                 $SETUP FOR TWICE THRU LOOP 01220C00 D
                                   $LOOP BEGINS HERE                                    01230000 D
                                   $                                                    01240000 D
0051  4009 E001 1030 00F0          A3 L=:A3                     $MAKE ROOM FOR MSB      01250C00 D
0052  9000 0000 0030 0030          COMP 3=:SAR                                          01260C00 D
0053  4009 0C41 0B90 00FC          B C=:B,MIR                                           01270C00 D
0C54  0000 000D 0000 0030          COMP 0=:SAR                                          01280C00 D
0C55  4009 AC56 0B00 00F0          A1 AND B=:B                                          01290C00 D
0056  4036 EC5C 1D90 00F0          B OR A3=:A3,BMI; CALL                                01300C00 D
                                   $END OF LOOP                                         01310C00 D
                                   $                                                    01320C00 D
                                   $OPCODE IS NOW IN LSB OF B                           01330C00 D
                                   $IF NOT ADV THEN OPC<60 =>TYPE 1                     01340C00 D
0057  4009 E15E 0000 00F0          A3 LSS LIT                                           01350C00 D
0C58  0300 0000 0030 00E0          48=:LIT                      $OPCODE = 60OCTAL       01360C00 D
0C59  7C19 E150 0C00 00F0          IF FALSE THEN A3 LEQ LIT;SKIP                        01370C00 D
005A  0110 0000 0030 C040          TYPE1-1=:MPCR                                        01380C00 D
                                   $IF NOT ADV THEN OPC<=61  =>TYPE 4A                  01390C00 D
005B  0310 0000 0000 00E0          49=:LIT                      $OPCODE =61 OCTAL       01400C00 D
005C  7C19 E15E 0000 00F0          IF FALSE THEN A3 GEQ LIT;SKIP                        01410C00 D
005D  0120 0000 0000 0040          TYPE4A-1=:MPCR                                       01420C00 D
                                   $IF ADV THEN OPCODE>=70  =>TYPE 4A                   01430C00 D
                                   $ELSE TYPE 4B                                        01440C00 D
005E  0300 0000 0030 00E0          56=:LIT                      $OPC=70 OCTAL           01450C00 D
005F  7019 0000 0030 00F0          IF FALSE THEN SKIP                                   01460C00 D
0C60  013C 0000 0000 0040          TYPE4A-1=:MPCR                                       01470C00 D
                                   $INSTRUCTION IS TYPE 4B - OPCODE STILL IN A3          01480C00 D
                              TYPE4B:                                                   01490C00 D
0C61  0D50 00C0 003C 00E0          COLSX8=LIT                                           01500C00 D
0062  014C 0000 0000 0060          READAFIELD-1=:CPCR           $FETCH COLS 5-8 INTO B  01510C00 D
0C63  4009 E001 1000 C0F0          A3 L=:A3                                             01520000 D
0C64  9000 000D 0030 0030          COMP 3=:SAR                                          01530C0C D
0C65  4009 0C41 0B90 00F0          B C=:B,MIR                                           01540C00 D
0C66  0000 0000 0000 0030          COMP 0=:SAR                                          01550C00 D
0067  4005 AC56 0B00 00F0          A1 AND B=:B                  $A1 STILL HAS 7         01560C00 D
0C68  4009 EC5C 1D00 00F0          A3 OR B=:A3,BMI                                      01570C0C D
0069  4009 0C41 0B90 C0F0          B C=:B,MIR                                           01580C00 D
006A  4009 E001 1030 C0F0          A3 L=:A3                     $MAKE ROOM FOR MSB OF "M" 01590C00 D
0C6B  000C 0000 0000 C030          COMP 1=:SAR                                          01600C0C D
006C  4012 E05C 1D00 00F0          A3 OR BOOT=A3,BMI;SAVE                               01610C00 D
                              $SETUP FOR TWO PASS LOOP FOR REST OF "M"                  01620000 D
006D  4009 E001 1030 00F0          A3 L=:A3                                             01630000 D
006E  900C 000D 0030 0030          COMP 3=:SAR                  $GET NEXT DIGIT OF M TWICE 01640C00 D
006F  4009 0C41 0B90 00F0          B C=:B,MIR                                           01650C00 D
0070  0000 0000 0000 C030          COMP 0=:SAR                                          01660000 D
0071  4009 AC56 0B00 C0F0          A1 AND B=:B                                          01670C00 D
0072  4036 EC5C 1D90 00F0          A3 OR B=:A3,BMI;CALL                                 01680000 D
                                   $END OF LOOP                                         01690C00 D
0073  0150 000D 0030 0040          OUTPUT-1=:MPCR               $WORD WAS BUILT INTO LOWER A3 01700C00 D
                                   $                                                    01710C0C D
                              TYPE4A:          $OPCODE IS STILL IN A3                    01720C0C D
0074  005C 0000 0030 00E0          COLSX8=LIT                                           01730C00 D
0075  016C 0000 0000 0060          READAFIELD-1=:CPCR           $FETCH FIELDS A,F4,B,I  01740C00 D
0076  4052 0000 0000 00F0          SET LC2;SAVE                                         01750C0C D
                                   $START 3 PASS LOOP HERE                              01760000 D
0077  4009 E001 1000 00F0          A3 L=:A3                                             01770C00 D
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0C78  9000 0000 0030 0030          COMP 3=:SAR                                          01780000 D
0C79  9809 0C41 0B00 00F0          B C=:B,MIR                                           01790000 D
0C7A  0000 0000 0000 0030          COMP 0=:SAR                                          01800000 D
0C7B  9809 AC56 0B00 00F0          A1 AND B=:B                                          01810000 D
0C7C  9809 EC5C 1D90 00F0          A3 OR B=:A3,BMI                                      01820000 D
0C7D  302E 00C0 0090 C0F0          IF LC2 THEN JUMP ELSE CALL                           01830000 D
                                   %END LOOP                                            01840000 D
                                   %                                                    01850000 D
0C7E  9809 E0C1 1C90 00FC          A3 L=:A3,BEX                                         01860000 D
0C7F  B00C 0000 0000 0030          COMP 1=:SAR                                          01870000 D
                                   %INSERT I FIELD                                      01880000 D
0C80  9809 E05C 1000 00F0          A3 OR BOOT=:A3                                       01890000 D
0C81  0170 0000 0000 C040          OUTPUT-1=:MPCR              %DONE TYPE 9A            01900000 D
                                   %RESULTS IN A3                                       01910000 D
                                   %                                                    01920000 D
                            TYPE1:          %OPCODE IS IN A3                           01930000 D
0C82  0D50 0000 0090 00E0          COL5X8=LIT                                           01940000 D
0C83  0180 0000 0000 0060          READAFIELD-1=:CPCR          %FETCH A,K,B,I FIELDS    01950000 D
0C84  4852 0000 0090 00F0          SET LC2;SAVE                                         01960000 D
                                   %START 3 PASS LOOP HERE                              01970000 D
0C85  9809 E001 1C90 00F0          A3 L=:A3                                             01980000 D
0C86  9000 00C0 0090 0030          COMP 3=:SAR                                          01990000 D
0C87  9809 0C41 0B00 00F0          B C=:B,MIR                                           02000000 D
0C88  000C 0000 0090 0030          COMP 0=:SAR                                          02010000 D
0C89  9809 AC56 0B0C C0F0          A1 AND B=:B                                          02020000 D
0C8A  9809 EC5C 1D9C 00F0          A3 OR B=:A3,BMI                                      02030000 D
0C8B  302E 00C0 0090 00F0          IF LC2 THEN JUMP ELSE CALL                           02040000 D
                                   %END LOOP A,K,B FIELDS INSERTED NOW GET I FIELD      02050000 D
0C8C  9809 E001 1C90 00F0          A3 L=:A3,BEX                                         02060000 D
0C8D  B00C 0000 0090 C030          COMP 1=:SAR                                          02070000 D
0C8E  9809 E05C 1000 00F0          A3 OR BOOT=:A3                                       02080000 D
0C8F  0D60 00C0 0090 00EC          COL9X12=LIT                                          02090000 D
0090  0170 0000 0090 0060          READAFIELD-1=:CPCR                                   02100000 D
0C91  9809 E0C1 1C00 C0F0          A3 L=:A3                                             02110000 D
0C92  9000 0000 0000 0030          COMP 3=:SAR                 %INSERT S FIELD          02120000 D
0C93  9809 0C41 0B00 00F0          B C=:B,MIR                                           02130000 D
0C94  0000 0000 0090 C030          COMP 0=:SAR                                          02140000 D
0C95  9809 AC56 0B90 00F0          A1 AND B=:B                                          02150000 D
0C96  9809 EC5D 1D9C 00F0          A3 OR B L=:A3,BMI                                    02160000 D
0097  B000 0000 0000 0030          COMP 1=:SAR                                          02170000 D
0C98  9809 0C41 0B9C 00F0          B C=:B,MIR                                           02180000 D
0099  0000 0000 0090 0030          COMP 0=:SAR                                          02190000 D
                                   %MSB OF Y HAS BEEN INSERTED                          02200000 D
0C9A  9849 E05C 1D90 00F0          A3 OR BOOT=:A3,BMI;SET LC2                           02210000 D
                                   %START TWO - TWO PASS LOOPS HERE FOR REMAINDER OF Y FIELD 02220000 D
0C9B  4812 0000 0090 C0F0   YFIELD: SAVE                                               02230000 D
0C9C  9809 E0C1 1090 C0F0          A3 L=:A3                                             02240000 D
0C9D  9000 0000 0090 0030          COMP 3=:SAR                                          02250000 D
0C9E  9809 0C41 0B80 00F0          B C=:B,MIR                                           02260000 D
0C9F  0000 0000 0090 0030          COMP 0=:SAR                                          02270000 D
00A0  9809 AC56 0B90 00F0          A1 AND B=:B                                          02280000 D
00A1  9836 EC5C 1D90 00F0          A3 OR B=:A3,BMI; CALL                                02290000 D
                                   %END OF LOOP                                         02300000 D
                                   %                                                    02310000 D
00A2  0D7C 00C0 0090 00E0          COL13X16=LIT                                         02320000 D
00A3  01A0 0000 0090 0060          READAFIELD-1=:CPCR                                   02330000 D
00A4  3419 E0C0 0090 00F0          IF NOT LC2 THEN A3=MIR; SKIP ELSE STEP               02340000 D
00A5  09AC 0000 0000 0040          YFIELD-1=:MPCR                                       02350000 D
                                   %COMPLETED Y                                         02360000 D
                                   %COMPLETED TYPE 1 NOW SAVE IN MIR AND OUTPUT         02370000 D
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0CA6  01BC 0000 0C00 0040          NOPACK-1=MPCR                                          02380C00 D
                                   %                                                      0239CC00 D
                                   %IF TYPE 4 INSTRUCTION THEN IF LOWER HALF OF PREVIOUS  02400C00 D
                                   %INSTRUCTION WAS ZERO AND IN THIS INSTRUCTION AND      02410C00 D
                                   %AND OUTPUT, ELSE SHIFT THIS INSTRUCTION TO UPPER &ALF 02420C00 D
                                   %AND OUTPUT AND ADVANCE PAR.                           02430C00 D
                                   %                                                      0244CC00 D
                                OUTPUT:                                                   02450C00 D
0CA7  4809 C00E 001C 00F0          A2-1=:MAR2                                             02460C00 D
0CA8  A809 C008 0000 0CF0          MR2;IF RDC                 %READ PREVIOUS INSTRUCTION  02470C0C D
0CA9  AC08 0000 0C00 00F0          WHEN RDC THEN BEX                                      02480C00 D
0CAA  4809 0C41 0B00 00F0          B L=:B                     %CHECK LOWER HALF FOR ZEROS 02490C00 D
0CAB  000C 0008 0030 0020          COMP 16=:SAR                                           025CCC00 D
0CAC  01CC 0008 0000 00C0          PACKLEFT-1=:AMPCR          %IF NOT THEN WRITE UPPER ONLY 02510C0C C
0CAD  4809 0C42 C000 C0F0          NOT B                                                  02520C00 D
0CAE  6C00 0008 0C00 00F0          IF ABT THEN BEX;STEP ELSE JUMP                         02530C00 C
0CAF  4809 EC5C 0030 00F0          A3 OR B=:MIR               %JOIN INSTRUCTION INTO LOWER &ALF 02540C00 D
                                WRITEOUT:                                                 02550C00 D
0CB0  01D0 0008 0000 0040          OUT-1=MPCR                                             02560C00 D
                                PACKLEFT:                                                 02570C00 D
0CB1  4809 E001 0030 00F0          A3 L=:MIR                  %MOVE INSTRUCTION TO UPPER HALF 02580000 D
0CB2  0000 0008 0030 0020          COMP 16=:SAR                                           02590C00 D
0CB3  4809 C00D 001C 00F0          NOPACK: A2=MAR2                                        02600C00 D
0CB4  4809 C0C8 2C00 00F0          A2+1=:A2                   %UPDATE PAR                 0261CC00 D
0CB5  01E0 0008 0030 0040          OUT-1=MPCR                                             02620C00 D
                                   %                                                      02630C00 D
                                READAFIELD:    %RETURN CONTENTS OF BUFFER ADDRESSES BY LIT 02640C00 D
0CB6  4809 2003 001C 00F0          LIT=:MAR2                                              0265CC00 D
0CB7  A809 0008 0000 0CF0          MR2;IF RDC                                             02660C00 D
0CB8  AC28 0008 0C00 00F0          WHEN RDC THEN BEX; JUMP                                02670C00 D
                                   %END OF INSTRUCTION SETUP ROUTINES                     02680C00 D
                                   %                                                      02690C00 D
                                %                                                         02700C00 D
                                ORIGIN:                                                   0271CC00 D
0CB9  01F0 00C0 0000 0060          GETADDR-1=:CPCR                                        02720C00 D
                                   %GET NEW ADDRESS AND PUT INTO P-REG LOCATION COUNTER 106 02730C00 D
0CBA  4809 2003 001C 00F0          LIT=:MAR2                                              02740C00 D
0CBB  070C 0008 0030 00A0          PLOC=LIT;16=SAR                                        02750C00 D
0CBC  4809 00C1 0B30 00F0          1 L=:B                     %OFFSET BY 1024             02760C00 D
0CBD  A000 0008 0000 0020          COMP 10=:SAR                                           0277000C D
0CBE  4809 EC4B 2030 00F0          A3+B=MIR,A2                                            02780C00 D
0CBF  0200 0008 0C30 0040          OUT-1=MPCR                                             02790C00 D
                                   %                                                      02800C00 D
                                   %                                                      02810C00 D
                                SETINDEXREG:   %GET REG NUMBER FROM WORD IN COL 7-8, BUFFER 199 02820C00 D
                                   %SAVE IN A3,AFTER OFFSETTING BY 9. PASS CONTROL TO SETREG 0283C000 D
                                   %WHICH WILL DECIPHER VALUE AND STORE IN PROPER REGISTER. 0284CC00 D
                                   %MAR ASSUMED STILL SET AT 198                          0285CC00 D
                                   %                                                      02860C0C D
0CC0  0210 0008 0000 0060          GETADDR-1=:CPCR             %VALUE RETURNED IN A3      0287CC00 D
0CC1  4809 E140 1030 00F0          A3 + LIT =:A3                                          02880C00 D
0CC2  0000 0008 0C00 00E0          BBASE=LIT                                              02890C00 D
0CC3  0220 00C0 0030 C040          SETADDR-1=:MPCR                                        029C0C00 D
                                   %                                                      02910C00 D
                                   %                                                      02920C00 D
                                SETAREG:       %GET REG NUMBER FROM COL 7-8 WORD 199 SAVE IN A3. 0293CC00 D
                                   %PASS CONTROL TO SETREG WHICH WILL DECIPHER VALUE AND   02940C00 D
                                   %STORE IN REG.MAR STILL SET TO REREAD 198               02950C00 D
                                %                                                         02960C00 D
0CC4  0230 0008 0000 0060          GETADDR-1 =:CPCR            %VALUE RETURNS IN A3       02970C00 D
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00C5  0240 0040 0000 0040          SETADDR-1=:MPCR                                          02980C00 D
                                   %END SETAREG                                             02990000 D
                                   %                                                        03000C00 D
                                SETSWITCHES:                                                03010C00 D
                                   %%SWITCH VALUE WILL BE IN COL 4 OF CARD OR BITS 12-14 OF A3  03020C0C D
                                   %MASK VALUE AND WRITE TO ADDRESS 64                      03030C00 D
00C6  0250 0000 0030 0060          GETADDR-1=:CPCR                                          03040C00 D
00C7  4809 E0C0 0090 00FC          A3=MIR                                                   03050C00 D
00C8  0580 0000 0C90 00E0          SWITCH=LIT                                               03060C00 D
00C9  4809 2003 0C1C 00F0          LIT=MAR2                                                 03070C00 D
00CA  0260 00C0 0030 0040          OUT-1=MPCR                                               03080C00 D
                                   %                                                        03090C00 D
                                   %                                                        03100C00 D
                                IFETCH:                                                     03110C00 D
                                   %ROUTINE SETS UP PAR AND GOES TO A LOOP CHECKING GC1     03120C00 D
                                   %WHICH WILL BE SIGNAL TO DO I/O. RETURNS TO OTHER PROCESSOR  03130C00 D
                                   %AFTER CLEARING GC1                                      03140C00 D
00CB  0270 0000 0030 0060          GETADDR-1=:CPCR                                          03150C00 D
00CC  4809 E0C0 0090 00F0          A3=MIR                                                   03160C00 D
00CD  4809 2003 0C1C 00F0          LIT=:MAR2                                                03170C00 D
00CE  01D0 00C0 0030 00E0          PAR=LIT                                                  03180C00 D
00CF  0280 00C0 0C00 C060          OUTPUT1-1=CPCR                                           03190C00 D
00D0  4949 0000 0000 00FC          RESET GC1                                                03200C00 D
00D1  0290 0000 0000 0040          IOREQ-1=MPCR                                             03210C00 D
                                   %                                                        03220000 D
                                   %                                                        03230C00 D
                                LOADERADDRESS:  %SETUP ADDRESS TO LOAD PROGRAM INTO. ADDRESS WILL BE  03240C0C D
                                   %ADDED TO 1024 FOR CORRECT LOADING. NUMBER WILL BE WRITT  03250C00 D
                                   %8 BASE REGISTERS      LOCATION COUNTER WILL BE STORED AT 20C  03260000 D
                                   %AND CAN ALSO BE MODIFIED BY "0" CARD                    03270C00 D
                                   %SET BASE REGISTER IN INCREMENTS OF 8192                 03280C00 D
                                   %                                                        03290C00 D
00D2  02A0 0000 0030 0060          GETADDR-1=:CPCR            %LOCATION RETURND IN A3       03300C00 D
00D3  4809 00C1 0B90 00F0          1 L=B,MIR                                                03310C00 D
00D4  A180 0000 0030 00A0          COMP 10=SAR;SBASE=LIT                                    03320C00 D
00D5  4809 EC40 1090 00F0          A3+B=A3                    %ADD 1024 TO OFFSET ADDRESS   03330C0C D
00D6  4809 2003 001C 00F0          LIT=MAR2                                                 03340C00 D
00D7  4809 00C1 4000 00FC          1 L=A1                                                   03350000 D
00D8  3070 0009 0C30 C0A0          7=LIT;COMP 13=SAR                                        03360C00 D
00D9  4812 0000 0091 C0F0          LCTR;SAVE                                                03370000 D
00DA  9809 0008 0D90 1CF0          MV2;BMI;IF SAI                                           03380C00 D
00DB  9C08 AC40 0C92 00F0          WHEN SAI THEN A1+B=MIR,INC                               03390000 D
00DC  8429 0F46 0C1C 00F0          IF NOT COV THEN BMAR+1=MAR2;JUMP                         03400C00 D
00DD  4809 E000 0B90 00F0          A3=MIR,B                                                 03410C00 D
00DE  4809 2003 0C1C 00F0          LIT=MAR2                   %ADDRESS OF LOCATION COUNTER  03420C00 D
00DF  0780 00C0 0030 00E0          PLOC=LIT                                                 03430C00 D
                                   %A2 NOW HAS SECTOR ADDRESS/LOCATION COUNT                03440C00 D
00E0  4809 C000 A070 40F0          A2 R=:A2,CSAR                                            03450C00 D
00E1  0000 0009 0090 0020          16=:SAR                    %GET LOAD ADDRESS INTO LOW ORDER OF AC  03460C00 D
00E2  4809 C001 2000 C0F0          A2 L=:A2                   %A2=SECTOR ADDRESS/LOCATION COUNTER  03470C00 D
00E3  4809 CC5C 2030 00F0          A2 OR B =:A2                                             03480C0C D
00E4  9809 0008 0000 1CFC  OUT:    MV2;IF SAI                                               03490000 D
00E5  9C08 0009 0030 00FC          WHEN SAI THEN 0; STEP                                    03500C00 D
                                   %8 REGISTERS 24-31 SET AND LOCATION COUNTER 106 SET      03510000 D
                                   %                                                        03520C00 D
                                %                                                           03530C00 D
                                NEWWRD:                                                     03540C00 D
                                CARDREAD:                                                   03550000 D
                                   %ROUTINE USES A1,B,MIR                                   03560C00 D
                                   %THIS ROUTINE PLACES A 0/190 INTO MAILBOX                03570C00 D
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                        %THIS SHOULD READ 20 WORDS INTO ADDRESS 334(8)                          03580C00 D
00E6  4809 0000 0901 00F0       0=BC8,LCTR                                                      03590C00 D
00E7  0210 00C0 0030 00E0       33=LIT                                                          03600C00 D
00E8  4809 20C3 001C 00F0       LIT=MAR2                                                        03610C00 D
00E9  002C 0000 0030 C0A0       HEXADDR=LIT;COMP 16=SAR                                         03620C00 D
00EA  4809 0C40 0030 C0F0       B=MIR                                                           03630C00 D
00EB  0200 0000 0000 C060   ZBUFF:  OUTPUT1-1=CPCR                                              03640C00 D
00EC  0400 0F46 001E C0F0       IF NOT COV THEN BMAR+1=MAR2,INC;STEP ELSE SKIP                  03650C00 D
00ED  0EA0 00C0 0C30 0040       ZBUFF-1=MPCR                                                    03660C00 D
00EE  9009 2000 0030 00F0   CARDFETCH:          LIT =: MIR; IF SAI                              03670C00 D
00EF  0040 0000 0030 00E0       CARDBUF=LIT                                                     03680C00 D
00F0  02C0 00C0 0C30 C060       EXTOP-1 =: CPCR                                                 03690C00 D
00F1  0EDC 0000 009C 0040       CARDFETCH-1 =: MPCR         %COULDNOT READ CARD                 03700C00 D
00F2  4809 C001 4030 00F0       A2 L=A1                     %PUT ADDRESS IN A1                  03710C00 D
00F3  0020 00C0 0030 C090       HEXADDR=LIT;COMP 20=SAR                                         03720C00 D
00F4  4809 20C3 001C 00F0       LIT=MAR2                    %ADDRESS BEFORE CARDBUFFER          03730C00 D
00F5  4812 0000 C091 00F0       0=MIR,LCTR;SAVE             %LOOP 4 _IMES FOR ADDRESS           03740C00 D
00F6  003C 0000 0030 00B0       COMP 0=SAR;3=LIT                                                03750C00 D
00F7  9809 0C41 0092 C0F0       B L=MIR,INC;IF SAI                                              03760000 D
00F8  4809 A000 0F30 C0F0       A1 R=BBI                                                        03770000 D
00F9  9000 0000 0030 0030       COMP 3=SAR                                                      03780C00 D
00FA  4809 A001 4030 00FC       A1 L=A1                     %MSB OR 71R                         03790C00 D
00FB  4809 0C40 0030 C0F0       B=MIR                                                           03800C00 D
00FC  8A00 0000 0C90 1CF0       IF COV THEN MW2;STEP ELSE JUMP                                  03810C00 D
00FD  9C08 2000 007C C0F0       WHEN SAI THEN LIT=MIR,MAR2                                      03820C00 D
00FE  0D40 0000 0030 C0B0       CARDBUF=LIT;24=SAR                                              03830C00 D
00FF  0200 0000 0030 0060       INPUT-1=CPCR                %CHECK F3R INSTRUCTION              03840C00 D
0100  4809 0C40 8B30 C0FC       B R=B                       %  OR CONTROL CARD                  03850C00 D
0101  4809 2C52 0030 C0F0       LIT EQL B                                                       03860C00 D
0102  0300 0000 0030 00A0       48=LIT;16=SAR               %SPACE " "                          03870C00 D
0103  6C08 2000 0030 00F0       IF TRUE THEN LIT=MIR;STEP ELSE SKIP                             03880C00 D
0104  0020 00C0 0030 00A0       HEXADDR=LIT;16=SAR                                              03890000 D
0105  DC19 00C1 0F00 00F0       IF IRQ THEN 1 L=BBI;SKIP                                        03900C00 D
0106  021C 00C0 0030 C040       CHECKCOL1-1=MPCR                                                03910C00 D
0107  4809 0C40 0030 00F0       B=MIR                                                           03920000 D
                        CARDPRINT:                      %ECHO CARD READ                         03930C00 D
0108  02EC 00C0 009C C060       EXTOP-1 =: CPCR                                                 03940C00 D
0109  1070 00C0 0030 0040       CARDPRINT-1=MPCR            %ERROR RETURN FOR PRINTING          03950C00 D
010A  0210 00C0 0030 C040       CHECKCOL1-1=MPCR                                                03960C00 D
                        %                                                                       03970000 D
                        %                                                                       03980000 D
                        EXTOP:          %THIS ROUTINE PERFORMS REQUESTED EXTERNAL INTERFA       03990C00 D
                                        %TO THE IOP MIR = FUNCTION/ADDRESS                      04000C00 D
                                        %RETURNS CONDITION OF OP IN B                           04010C00 D
010B  1C88 0002 0C2C 00F0       SET GC2 WHEN GC2 THEN NOT 0 =: MAR1                             04020000 D
010C  9009 00C0 0030 18F0       MW1; IF SAI                                                     04030C00 D
010D  9F08 0000 0030 00F0       WHEN SAI THEN 0; SET INT                                        04040C00 D
010E  0009 00C0 0030 00F0       IF INT                                                          04050C00 D
010F  0008 0000 0030 00F0       WHEN INT THEN STEP                                              04060C00 D
0110  A009 0000 0C30 08F0       MR1;IF RDC                                                      04070C00 D
0111  AEC8 0000 0C30 C0F0       WHEN RDC THEN BEX; RESET GC2                                    04080C00 D
0112  4809 0C42 0C0C 00F0       NOT B                       %B=0 IS ERROR RETURN ELSE JUMP      04090C00 D
0113  602F 0000 0090 C0F0       IF ABT THEN JUMP ELSE RETN                                      04100C00 D
                        %END EXTERNAL FUNCTION                                                  04110C00 D
                        %                                                                       04120C00 D
                        GETADDR:                                                                04130000 D
                        %ASSUME MAR2 IS SET UP TO REREAD AAME WORD VIA BEX. RESULT WILL         04140C00 D
                        %BE RETURNED IN A3, 7MIR CONTAINS ADDRESS OF WORD                       04150C00 D
0114  4809 0000 0C00 00F0       BEX                                                             04160C00 D
0115  4809 0003 1011 00F0       0 =: A3,BR2,LCTR            %FIRST DIGIT IS LAST BYTE OF B      04170C00 D
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0116  0030 00C0 0C3C 0080          COMP 8 =:SAR;3=:LIT                                          04180000 D
0117  9009 2C57 1090 00F0          B AND LIT L =: A3          %COL 4 NOW IN A3 (4-6)            04190C00 D
0118  9070 00C0 0090 C0BC          7=:LIT;COMP 3=:SAR                                           04200C00 D
0119  9009 20C3 001C 00F0          LIT=:MAR2                                                    04210C00 D
011A  0050 0000 0090 C0E0          COL5X8=LIT                                                   04220C00 D
011B  A009 0C00 0090 0CF0          MR2;IF RDC                                                   04230000 D
011C  AC08 0000 0C90 00F0          WHEN RDC THEN BEX                                            04240C00 D
0110  9009 0C41 0B90 00F0  GETADDRLOOP:    B C =: B,MIR       %SHIFT TO GET BYTE LSB AND SAVE   04250C00 D
011E  007C 00C0 0090 00BC          COMP 8 =: SAR; 7 =: LIT                                      04260C00 D
011F  9009 2C56 0B02 00F0          B AND LIT =: B,INC                                           04270000 D
0120  9009 EC5D 1D90 40F0          A3 OR B L=A3,BMI,CSAR                                        04280C00 D
0121  9000 0000 0090 0030          COMP 3 =: SAR                                                04290C00 D
0122  0C29 E009 9000 00F0          IF COV THEN A3 R=A3; JUMP ELSE STEP                          04300C00 D
0123  11CC 00C0 0090 0040          GETADDRLOOP-1 =: MPCR                                        04310C00 D
                                   %                                                            04320C00 D
                                   %                                                            04330000 D
                           SETADDR:        %SET THE REGISTER ADDRESSED IN A3 TO VALUES IN COLS 9-16 04340C00 D
                                           %FOUND IN BUFFERS 199 & 200                          04350C00 D
                                   %                                                            04360C00 D
0124  9849 20C3 001C 00F0          LIT=MAR2;SET LC2                                             04370C00 D
0125  0D6C 0009 0090 00E0          COL9X12=LIT                                                  04380C00 D
                                   %GET COLUMNS 9-12                                            04390C00 D
0126  02F0 0000 0000 C060          INPUT-1=CPCR                                                 04400C00 D
0127  9009 0C40 4090 00F0          B=A1                       %A1 HAS VALUE                     04410C00 D
0128  9009 A0C1 4C01 00F0          A1 L=A1,LCTR               %GET 2 MSB LEFT                   04420C00 D
0129  202C 0000 0090 00BC          COMP 6=SAR;2=LIT                                             04430000 D
012A  9009 A0C0 8B00 00F0          A1 R=B                     %B HAS 2MSB OF NEXT 3 CHARS       04440C00 D
012B  A000 0000 0000 0030          COMP 2=SAR                                                   04450000 D
012C  9012 A0C1 4000 00F0          A1 L=A1;SAVE                                                 04460C00 D
012D  9009 A001 4090 00F0  SETLOOP:  A1 L=A1                  %GET NEXT 3 BITS LEFT             04470C00 D
012E  3000 00C9 009C 0030          COMP 5=SAR                                                   04480C00 D
012F  9009 0C41 0C30 00F0          B L=MIR                                                      04490C00 D
0130  9000 00C0 0C90 0030          COMP 3=SAR                                                   04500C00 D
0131  9009 A000 8F00 00F0          A1 R=BBI                                                     04510C00 D
0132  9009 A0C1 4002 C0F0          A1 L=A1,INC                                                  04520C00 D
0133  9009 0C40 0C90 00F0          B=MIR                                                        04530C00 D
0134  0C19 0F46 0D1C C0F0          IF COV THEN BMAR+1=MAR2,BMI;SKIP                             04540C00 D
0135  12CC 00C0 0090 0040          SETLOOP-1=MPCR                                               04550C00 D
0136  A009 00C0 C090 0CF0          MR2;IF ROC. WHEN RDC THEN BEX                                04560000 D
0137  AC08 0C00 0C90 C0FC
0138  9009 0C40 4D01 00F0          B=A1,LCTR,BMI                                                04570C00 D
0139  0030 0000 0000 00E0          3=LIT                      %RETURN 3 TIMES FOR COLS 17-19    04580C00 D
013A  3435 00C0 0092 C0F0          IF NOT LC2 THEN INC; CALL ELSE JUMP                          04590C00 D
013B  9009 E0C3 0C1C C0FC          A3=MAR2                                                      04600C00 D
013C  0E50 0009 0090 00C0          NEWWRD-1=AMPCR                                               04610C00 D
                           OUTPUT1:                                                             04620C00 D
013D  9009 0000 0090 1CF0          MW2;IF SAI                                                   04630C00 D
013E  9C20 0009 0090 00F0          WHEN SAI THEN 9;JUMP                                         04640C00 D
013F  A009 00C0 0090 CCF0  INPUT:  MR2;IF RDC                                                   04650C00 D
0140  AC20 0000 0C90 00FC          WHEN RDC THEN BEX;JUMP                                       04660C00 D
                                   %                                                            04670C00 D
                           DUMP:                                                                04680C00 D
0141  113C 0009 0090 C06C          GETADDR-1=:CPCR            %A3=ADDRESS IN COLS.9-8           04690C00 D
                           IODUMP:                                                              04700C00 D
0142  9009 C009 0090 00FC          A2=:MIR                                                      04710C00 D
                                   %A2 SAVED AWAY AS TEMPORARY FOR FUTURE RESTORATION           04720000 D
0143  9009 20C3 001C 00F0          LIT=MAR2                                                     04730C00 D
0144  0780 0003 0000 C0A0          PLOC=LIT;COMP 16=SAR                                         04740C00 D
0145  9009 20C0 0B3C C0F0          LIT=8                                                        04750C00 D
0146  0240 0090 0C00 C0E0          NUMLINES=LIT               %NUMBER OF ADDRESSES TO PRINT     04760C00 D
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0147  13C0 C000 0C00 C06C          OUTPUT1-1=:CPCR                                          04770C00 D
0148  9809 2001 2000 00F0          LIT L =:A2                                               04780000 D
0149  0060 0000 0030 C0E0          6=:LIT                          %WORDS PER LINE=6        04790C0C D
014A  9809 CC5C 2030 C0F0          A2 OR B=:A2                     %A2=6/65=WDS PER LINE/65 WORDS 04800C00 D
014B  9809 E0C1 1090 00F0    SETBUFF: A3 L=A3                                               04810C00 D
014C  0EDC 00C0 0C30 C0A0          COMP 16=SAR;PRINTAREA-1=LIT                              04820000 D
014D  9809 E15C 1000 00F0          A3 OR LIT=:A3                   %A3=READ ADDR/BUFFER ADDR 04830C00 D
014E  9809 0C00 0900 C0F0          0=:BC8                          %B=30303030              04840C00 D
014F  9809 0C40 0091 C0F0          B=MIR,LCTR                                               04850C00 D
0150  021C 0000 0C00 C0E0          33=:LIT                                                  04860000 D
0151  9809 2003 001C 00F0          LIT=MAR2                                                 04870C00 D
0152  0EEC 0000 0C00 00E0          PRINTAREA=LIT                                            04880C00 D
                             ZEROLOOP:                                                     04890C00 D
0153  13C0 0000 0030 C060          OUTPUT1-1=:CPCR                                          04900C00 D
0154  8408 0F46 001E C0F0          IF NOT COV THEN BMAR+1=MAR2,INC; STEP ELSE SKIP          04910000 D
0155  152C 0000 0C30 C040          ZEROLOOP-1=:MPCR                                         04920C00 D
0156  9809 E0C0 C030 C0FC          A3 R=:A1                        %START BY PRINTING ADDRESS 04930000 D
0157  0080 0000 CC30 0020          16=:SAR                                                  04940C00 D
0158  9809 0000 0931 C0FC    CONVERT:  0=:BC8,LCTR                                         04950C00 D
0159  2010 0000 0030 C0DC          1=LIT;COMP 6=SAR                                         04960C00 D
015A  9809 0C41 0B30 C0F0          B L=:B                                                   04970C00 D
015B  9809 0C41 0090 00F0          B L=:MIR                                                 04980C00 D
015C  A00C 00C0 0C00 C030          COMP 2=SAR                                               04990C00 D
015D  9809 A0C0 8F90 C0F0          A1 R=:BBI                                                05000C00 D
015E  9809 A001 9030 00F0          A1 L=:A1                                                 05010C00 D
015F  9852 0000 0000 C0F0          SET LC2;SAVE                                             05020C00 D
                             CONVLOOP:                                                     05030C00 D
0160  9809 0C41 0B3C C0F0          B L=:B                          %BEGIN LOOP HERE         05040C00 D
0161  3000 00C0 0030 0030          COMP 5=:SAR                                              05050C00 D
0162  9809 0C41 0090 00F0          B L =:MIR                       %SHIFT A1 INTO B         05060C00 D
0163  9000 00C0 0030 C030          COMP 3=:SAR                                              05070C00 D
0164  9809 A0C0 8F90 00F0          A1 R=:BBI                                                05080000 D
0165  9809 A001 9002 00F0          A1 L=:A1,INC                                             05090C00 D
0166  8C19 E0C3 001C C0F0          IF COV THEN A3=MAR2;SKIP ELSE STEP                       05100C00 D
0167  15F0 0000 0030 0040          CONVLOOP-1=:MPCR                                         05110C00 D
0168  9809 E0C0 1090 00F0          A3+1=:A3                                                 05120000 D
0169  9809 0C40 0090 00F0          B=:MIR                          %B CONTAINS CONVERTED WORD 05130C00 D
016A  9809 0000 0030 1CF0          MW2;IF SAJ                                               05140CC0 D
016B  9C08 00C0 0931 00F0          WHEN SA1 THEN 0=:BC8,LCTR                                05150C00 D
016C  003C 00C0 0000 00E0          3=:LIT                                                   05160C00 D
016D  302E 00C0 0C30 C0FC          IF LC2 THEN JUMP ELSE CALL                               05170C00 D
                                   %END OF LOOP ONE 32 BIT WORD WRITTEN IN 3 WORDS          05180C0C D
016E  9809 C0C1 0B30 00F0          A2 L=:B                         %B=(UMBER WORDS/0        05190000 D
016F  0060 00C0 0030 00AC          COMP 16=:SAR;6=:LIT                                      05200C00 D
0170  0300 0000 00FC 00C0          FETCHWORD-1=:AMPCR                                       05210C0C D
0171  9809 C0C0 A09C C0FC          A2 R=:A2                                                 05220F00 D
0172  9809 C0DE 2090 C0F0          A2-1=:A2                        %SEE IF DONE ONE LINE YET 05230C00 D
0173  9429 CC5D A030 C0F0          IF NOT MST THEN A2 OR B C=:A2;JUMP                       05240000 D
0174  9809 2C41 A030 C0F0          LIT + B C=:A2                                            05250C00 D
0175  0310 0000 0080 0040          PRINTBUFF-1=:MPCR                                        05260C0C D
0176  9809 E0C0 1030 C0F0    FETCHWORD:  A3+1=A3                                           05270C00 D
0177  9809 E0C1 901C 00F0          A3+1 C=A3,MAR2                                           05280C00 D
0178  13E0 0000 0080 0060          INPUT-1=:CPCR                                            05290C00 D
0179  9809 C0DE 2095 00F0          A2-1=:A2,CTR                                             05300C00 D
017A  9809 0C40 9002 C0FC          B=A1,INC                                                 05310C0C D
017B  8408 E0C1 9000 C0F0          IF NOT COV THEN A3+1 C=A3;STEP ELSE SKIP                 05320C00 D
017C  157C 0000 0090 C040          CONVERT-1=:MPCR                                          05330C00 D
017D  9809 2003 001C C0F0          LIT=:MAR2                       %DONE ALL 65 WORDS       05340C00 D
017E  0780 0000 0030 00E0          PLOC=LIT                                                 05350C00 D
017F  13EC 0000 009C 0060          INPUT-1=:CPCR                                            05360C00 D
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0180  4809 0C40 2030 C0F0          B=:A2                          %RESTORE A2 FROM SAVED LOCATION      05370C00 D
0181  0E50 0000 0090 C0C0          NEWWRD-1=AMPCR                                                      05380C00 D
0182  2029 0000 0090 00F0          IF NOT LC1 THEN JUMP                                                05390C00 D
0183  0320 0000 0090 C040          IORETURN-1=MPCR                                                     05400C00 D
                                   $                                                                   05410C00 D
                              PRINTBUFF:                                                               05420C00 D
0184  4809 00C1 0B30 C0F0          1 L=:B                                                              05430C00 D
0185  0EE0 00C0 0090 00AC          COMP 16=SAR;PRINTAREA=LIT                                           05440C00 D
0186  4809 2C5C 0C90 C0F0          LIT OR B=:MIR                  %B=1/ADDRESS FOR PRINT BUFFER CODE   05450C00 D
0187  10A0 0000 0090 006C          EXTOP-1=:CPCR                                                       05460C00 D
0188  1030 00C0 0090 C040          PRINTBUFF-1=MPCR                                                    05470C00 D
0189  4809 EFC0 9C00 C0F0          A3 R=A3                                                             05480C00 D
018A  14AC 0000 0090 C040          SETBUFF-1=:MPCR                                                     05490C00 D
                              DATA:                               %INPUT DECIMAL DATA                05500C00 D
018B  49C9 20C3 001C 00F0          LIT=MAR2; SET LC1                                                   05510C00 D
018C  0060 0000 0090 00E0          COL9X12=LIT                                                         05520C00 D
018D  4809 00C0 0091 00F0          0=MIR,LCTR                                                          05530C00 D
018E  0030 0000 0090 C0E0          3=LIT                                                               05540C00 D
018F  13E0 0000 0090 006C     DATA1: INPUT-1=CPCR                                                      05550C00 D
0190  4812 0C40 4D30 C0F0          B=A1,BMI;SAVE                                                       05560000 D
0191  4809 A0C1 4030 C0F0          A1 L=A1                        %GET RID OF BCL HEADER               05570C00 D
0192  0000 0000 0090 0030          COMP 4=SAR                                                          05580C00 D
0193  4809 A0C0 900C C0FC          A1 R=A3                        %ISOLATE LOW ORDER 4 BITS            05590C00 D
0194  4809 A0C1 4030 C0F0          A1 L=A1                                                             05600C00 D
0195  4809 EC41 189C C0F0          A3 + B L=A3,BAD                %MULT BY 8                           05610000 D
0196  9000 00C0 0090 0030          COMP 3=SAR                                                          05620C00 D
0197  4809 0C41 0B3C 00F0          B L=B                          %MULT BY 2                           05630000 D
0198  B000 00C0 0090 0030          COMP 1=SAR                                                          05640C00 D
0199  4809 EC40 0B92 00F0          A3+B=B,MIR,INC                                                      05650C00 D
019A  BC0D 0F46 001C 00F0          IF COV THEN BMAR+1=MAR2; STEP ELSE JUMP                             05660C00 D
019B  0020 0000 0090 00EC          2=LIT                          %COUNTER SET FOR SECOND PASS FOR LOOP05670C00 D
019C  2C0F 0000 0091 00F0          IF LC1 THEN LCTR; STEP ELSE SKIP                                    05680C00 C
019D  10E0 00C0 009C 0040          DATA1-1=MPCR                                                        05690000 D
019E  4809 A0C1 4000 00F0          A1 L=A1                        %ADD IN LSP BYTE                     05700C00 D
019F  0000 0000 0090 0030          COMP 4=SAR                                                          05710C0C D
01A0  4809 A0C0 9C30 C0F0          A1 R=A3                                                             05720C00 D
01A1  4809 EC40 4B3C 00F0          A3+B=A1,B                      %COULD HAVE BEEN CALLED BY RESERVE   05730C00 D
01A2  3808 0000 0C90 C0F0          IF LC2 THEN STEP ELSE SKIP                                          05740C00 D
01A3  0330 0000 0C00 0040          RESERVE1-1=MPCR                                                     05750C00 D
01A4  4809 20C3 001C 00F0          LIT=MAR2                                                            05760C00 D
01A5  0D4C 0000 0090 C0E0          CARDBUF=LIT                                                         05770C00 D
01A6  13E0 0000 0090 C060          INPUT-1=CPCR                   %REREAD COLS 4-8 FOR ADDRESS         05780C00 D
01A7  113C 00C0 0090 0060          GETADDR-1=CPCR                                                      05790C00 D
01A8  4809 A000 0090 C0FC          A1=MIR                                                              05800C00 D
01A9  4809 E0C2 0090 C0F0          NOT A3                         %IF ADDR=0 PUT IN LINE               05810C00 D
01AA  600B 0000 0090 C0F0          IF ABT THEN STEP ELSE SKIP     %OTHERWISE PUT AT ADDRESS GIVEN      05820C00 D
01AB  0020 00C0 0C90 C040          NOPACK-1=MPCR                                                       05830C00 D
01AC  4809 00C1 C800 00FC          1 L=B                                                               05840C00 D
01AD  A00C 0000 0C0C 002C          COMP 10-SAR                                                         05850C00 D
01AE  4809 EC43 001C C0F0          A3+B=MAR2                      %OFFESET ADDRESS BY 1024             05860C0C D
01AF  13C0 0000 0090 0060          OUTPUT1-1=CPCR                                                      05870000 D
01B0  0E50 0000 0C90 C040          NEWWRD-1=MPCR                  %NORMAL RETURN TO GET NEXT CARD      05880C00 D
01B1  0D80 0010 001C 00F0     IOREQ: SET GC1; WHEN GC1 THEN B111=MAR2                                  05890C00 D
01B2  13E0 00C0 0090 0060          INPUT-1=CPCR                                                        05900C00 D
01B3  4809 0C40 C00C 00F0          B R=A1                                                              05910C00 D
01B4  0000 0000 0090 002C          COMP 16=SAR                                                         05920C00 D
01B5  4809 A640 0040 00F0          A1+AMPCR=AMPCR                                                      05930C00 D
01B6  0340 00C0 0C90 00C0          EXTIOREQ-1=AMPCR                                                    05940C00 D
01B7  4809 0800 0000 00F0          STEP                                                                05950000 D
01B8  4824 0C43 101C C0FC          B=MAR2,A3;EXEC                                                      05960C00 D
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0189  49F6 0000 0030 00F0          CALL;SET LC1                                                    05970000 D
                                 IORETURN:                                                       05980000 D
018A  4949 0019 0005 00F0          RESET GC1; B111=CTR                                           05990000 D
018B  4808 0000 0002 00F0          INC;WHEN COV THEN STEP                                        06000000 D
018C  1B00 0000 0030 0040          IOREQ-1=MPCR                                                  06010000 D
                                 EXTIOREQ:                                                       06020000 D
018D  0350 0000 0000 00C0          DUMPREG-1=AMPCR                                               06030000 D
018E  0360 0000 0000 00C0          DUMPADD-1=AMPCR                                               06040000 D
018F  0370 0000 0030 00C0          CARDIO-1=AMPCR                                                06050000 D
01C0  0380 0000 0030 00C0          DISKIO-1=AMPCR                                                06060000 D
01C1  0390 0000 0030 00C0          DISKWRITE-1=AMPCR                                             06070000 D
01C2  03A0 0000 0030 00C0          PRINTERIO-1=AMPCR                                             06080000 D
01C3  03B0 0000 0000 00C0          WORDIO-1=AMPCR                                                06090000 D
01C4  03CC 0000 0000 00C0          PRINTLINE-1=AMPCR                                             06100000 D
01C5  0000 0000 0000 00CC          START-1=AMPCR                                                 06110000 D
                                 DUMPREG:                                                        06120000 D
01C6  4809 0000 0030 00F0          STEP                          %SETUP ADDRESS OF BLANKLINE BUFFER  06130000 D
01C7  1F40 0000 0030 00C0          BLANKLINE=AMPCR                                               06140000 D
01C8  4809 0000 0000 00F0          STEP                          %ALLOW FOR TIMMING FOR AMPCR    06150000 D
01C9  4809 0640 0030 00F0          AMPCR=MIR                                                     06160000 D
01CA  4809 2001 0F30 00F0          LIT L=BBI                                                     06170000 D
01CB  001C 0000 0030 00A0          16=SAR;1=LIT                                                  06180000 D
01CC  4809 0C40 0030 00F0          B=MIR                         %OUTPUT BLANKS = 30303030       06190000 D
01CD  10A0 0000 0030 0060        OUTBLANK:  EXTOP-1=CPCR                                       06200000 D
01CE  1CC0 0000 0030 0040          OUTBLANK-1=MPCR                                               06210000 D
01CF  1410 0000 0030 0040          IODUMP-1=MPCR                                                 06220000 D
                                 DUMPADD:                                                        06230000 D
01D0  1410 0000 0030 0040          IODUMP-1=MPCR                                                 06240000 D
                                 CARDIO:                                                         06250000 D
                                   %READ ONE CARD INTO BUFFER ADDRESSED IN B,MAR2               06260000 D
01D1  4809 E0C1 1080 00F0          A3 L=A3                       %DROP MSB OF BR REG             06270000 D
01D2  0000 0000 0000 0020          COMP 16=SAR                                                   06280000 D
01D3  2009 E0C0 0090 00F0          A3 R=MIR;IF LC1                                               06290000 D
                                 CARDIO1:                                                        06300000 D
01D4  10A0 0000 0030 0060          EXTOP-1=CPCR                                                  06310000 D
01D5  103C 0000 0030 0040          CARDIO1-1=MPCR                                                06320000 D
01D6  1B70 0000 0030 0040          IORETURN-1=MPCR                                               06330000 D
                                 DISKWRITE:                                                      06340000 D
01D7  4800 0000 0000 00F0          WAIT                                                          06350000 D
                                 PRINTERIO:                    %ASSUME ERROR NUMBER IN A3      06360000 D
01D8  4809 000D 0931 00F0          D=BC8,LCTR                                                    06370000 D
01D9  0210 00C0 0030 00E0          33=LIT                                                        06380000 D
01DA  4809 20C3 001C 00F0          LIT=MAR2. PRINTAREA=LIT                                       06390000 D
01DB  0EE0 0000 0030 00E0
01DC  4812 0C40 0C30 00F0          B=MIR;SAVE                                                    06400000 D
01DD  9809 0000 0030 1CF0          MW2;IF SAI                                                    06410000 D
01DE  9C08 0000 0000 00F0          WHEN SAI THEN 0;STEP                                          06420000 D
01DF  8429 0F46 001E 00F0          IF NOT COV THEN BMAR+1=MAR2,INC;JUMP                          06430000 D
01E0  4809 E157 1800 00F0          A3 AND LIT L=A3,BAD       %MULTIPLY ERROR NUMBER BY 10        06440000
01E1  9070 0000 0000 00B0          COMP 3=SAR;7=LIT                                              06450000 D
01E2  4809 0C41 0B31 00F0          B L=B,LCTR                                                    06460000 D
01E3  809C 0000 0000 00B0          COMP 1=SAR;9=LIT                                              06470000 D
01E4  4809 EC40 1000 00F0          A3+B=A3                                                       06480000 D
01E5  4809 E643 401C 00F0          A3+AMPCR=MAR2,A1                                              06490000 D
01E6  1100 0000 0000 00C0          ERRORLIST=AMPCR                                               06500000 D
01E7  4809 20C0 1030 00F0          LIT=A3                                                        06510000 D
01E8  0ED0 0000 0000 00E0          PRINTAREA-1=LIT                                               06520000 D
01E9  13E0 0000 0030 0060        ERROR1: INPUT-1=CPCR                                          06530000 D
01EA  4809 0C40 0C30 00F0          B=MIR                                                         06540000 D
01EB  4809 E0C0 101E 00F0          A3+1=A3,MAR2,INC                                              06550000 D
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01EC  13CC 0008 0090 C060          OUTPUT1-1=CPCR                                                    0656CC00 D
01ED  0408 A0C3 9C1C C0F0          IF NOT COV THEN A1+1=A1,MAR2;STEP ELSE SKIP                       0657C000 D
01EE  1E80 0C00 0099 0040          ERROR1-1=MPCR                                                     0658C000 D
01EF  9809 00C1 0B30 C0F0          1 L=B                                                             0659C000 D
01F0  0EE0 0000 009C C0A0          COMP 16=SAR;PRINTAREA=LIT                                         06600C00 D
01F1  9809 2C5C 0090 C0FC          LIT OR B=MIR                                                      06610000 D
01F2  10A0 00C0 0090 C060  ERROR2: EXTOP-1=CPCR                                                      06620000 D
01F3  1F1C 0008 007C 0040          ERROR2-1=MPCR                                                     06630C00 D
01F4  1090 0008 0090 00C0          IORETURN-1=AMPCR                                                  06640C00 D
01F5  2029 0008 C000 00F0          IF LC1 THEN JUMP ELSE STEP                                        06650C00 D
01F6  0E50 0008 0090 0040          NEWWRD-1=MPCR                                                     06660C00 D
                           WORDIO:                                                                  0667CC00 D
01F7  13E0 0008 0090 0060          INPUT-1=CPCR                 %FETCH WORD TO BE PRINTED            0668CC00 D
01F8  9809 00D8 9C1C C0F0          B110=MAR2                    %WRITE WORD OUT TO MAILBOX+1         0669CC00 D
01F9  9809 0C48 0090 C0F0          B=MIR                                                             06700C00 D
01FA  13C0 0008 0C00 0060          OUTPUT1-1=CPCR                                                    0671CC00 D
01FB  9809 EP01 CB30 00F0          A3 L=B                       %GET ADDRESS INTO UPPER B            06720CC0 D
01FC  00E0 0008 0090 00AC          COMP 16=SAR;14=LIT                                                0673CC00 D
01FD  9809 2C2D 0080 C0F0          LIT OR B C=MIR               %SEND 14/ADDRESS                     0674CC00 D
                           WORDIO1:                                                                 0675CC0C D
01FE  10AC 0008 0C90 0060          EXTOP-1=CPCR                                                      0676CC0C D
01FF  1FDC 0008 0000 0040          WORDIO1-1=MPCR                                                    0677CC00 D
0200  1B9C 0CC8 C000 C04C          IORETURN-1=MPCR                                                   06780000 D
                           PRINTLINE:  %PRINT ONE LINE FROM BUFFER ADDRESSED IN B                   06790000 D
0201  2809 20C1 1000 00F0          LIT L=A3;IF LC1                                                   0680CC00 D
0202  0060 00C8 0C90 00A0          COMP 16=SAR; 6=LIT                                                06810C00 D
0203  9809 EF4C 0090 C0F0          A3 XOR BMAR=MIR              %MSB OF BMAR ALWAYS HAS A 7          06820C00 D
0204  10A0 0008 0000 0060  PRINTLINE1:  EXTOP-1=CPCR                                                 06830C00 D
0205  2038 00C8 0000 C040          PRINTLINE1-1=MPCR                                                 0684CC00 D
0206  1B9C 0008 0090 0040          IORETURN-1=MPCR                                                   06850000 D
                           DISKIO: %READ DISK AS IN MAILBOX  B CONTAINS CODE/ADDRESS                06860C00 D
0207  2809 0C48 009C 00F0          B=MIR;IF LC1                                                      06870C00 D
0208  10A0 0008 0000 0060  DISKERR: EXTOP-1=CPCR                                                     0688CC00 D
0209  2078 00C8 009C 004C          DISKERR-1=MPCR                                                    0689CC00 D
020A  1B90 0008 0090 C040          IORETURN-1=MPCR                                                   0690000C D
020B  9849 00C8 0090 C0FC  RESERVE:  SET LC2                    %RESERVE AMOUNT OF SPACE IN COLS.9-16 0691CC00 D
020C  10A0 0008 0090 C040          DATA-1=MPCR                                                       06920C00 D
020D  9809 CC48 2090 00F0  RESERVE1:  A2+B=A2                   %INCREMENT PROGRAM COUNTER           0693CC00 D
020E  9809 20C3 0C1C CCF0          LIT=MAR2                                                          0694C000 D
020F  0780 00C9 0000 00E0          PLOC=LIT                                                          0695C000 D
0210  0E30 0008 0000 0040          OUT-1=MPCR                                                        0696C000 D
                           WORD:   %W - ASSUME CHARACTER INPUT UNTIL FIRST QUOTE                    0697CC00 D
                                   %ELSE USE ENTIRE CARD AS CHARACTER STRING. USE ADDRESS           0698C000 D
                                   %IN COLS 4-8 ELSE NEXT LOCATION IF ZERO.                         0699CC00 D
0211  1130 00C8 009C 0060          GETADDR-1=CPCR                                                    07CCCC00 D
0212  9809 20C3 9C1C 00F0          LIT =A1,MAR2                                                      0701CC00 D
0213  A06C 0008 0000 00A0          COMP 10=SAR;COL9X12=LIT                                           07020C00 D
0214  9809 0013 8B3C 00F0          B111 R=B                                                          0703CC00 D
0215  3809 E802 0090 C0F0          NOT A3; IF LC2                                                    0704C000 D
0216  6E59 C0DE 1000 C0F0          IF ABT THEN A2-1=A3; SET LC2; SKIP                                0705C000 D
0217  9809 EC48 1C90 00FC          A3 +B=A3                                                          07060C00 D
0218  13E0 0008 0090 0060  WORD1:  INPUT-1=CPCR                 %READ 4 COLS. INTO B                 0707CC00 D
0219  8030 0008 0C90 00E0          3=LIT                                                             0708CC00 D
021A  9812 00C0 0001 C0F0          LCTR;SAVE                    %SET UP FOR 4 CHARACTERS             0709CC00 D
021B  9809 0C41 8B9C 00F0          B C=B,MIR                    %GET NEXT COLUMN                     0710CC00 D
021C  03F0 0008 0090 C0B0          63=LIT;COMP B=SAR            %MASK LEAST 6 BITS                   0711CC00 D
021D  9809 2C56 001C C0F0          LIT AND B=MAR2               %SAVE LEAST 6 BITS                   0712CC00 D
021E  9809 2F52 0090 00F0          LIT EQL BMAR                 %SEE IF ITS A QUOTE "                07130000 D
021F  6419 0008 0092 C0F0          IF FALSE THEN INC; SKIP ELSE STEP                                 0714C000 D
0220  03DC 0008 009C 0040          WORD2-1=MPCR                                                      0715CC00 D
```

```
0221  8C0D E0C3 1C1C C0F0          IF COV THEN A3+1=MAR2,A3; STEP ELSE JUMP                    07160C00 0
0222  3E49 E0C0 2000 00F0          IF LC2 THEN A3=A2;SET LC2  %USE NEXT ADDRESS FROM A2        07170000 0
0223  13C0 0000 0030 0060          OUTPUT1-1=CPCR                                              07180C00 0
0224  4009 A0C3 401C C0F0          A1+1=A1,MAR2                                                07190000 0
0225  2170 0000 0C00 00C0          WORD1-1=AMPCR                                               071A0C0C 0
0226  4009 A152 0C0C 00F0          A1 EOL LIT                                                  071B0C00 0
0227  0E00 0000 0070 C0E0          LASTCOL=LIT                                                 071C0C00 0
0228  6029 0000 0030 00F0          IF FALSE THEN JUMP          %218 = LAST COLUMN OF CARD      071D0C00 0
0229  3C09 E0C0 2000 C0F0  WORD2:  IF LC2 THEN A3+1=A2         %RESET PROGRAM COUNTER          071E0C00 0
022A  0E50 0000 0000 C040          NEWWRD-1=MPCR                                               071F0C00 0
0228  000C C0C0 0C00 C040          END                                                         07200C00 0
022C  2200 00C0 0070 C040   %END
01C4  2000 0000 0C00 00C0
01C3  1F60 0003 0030 00C0
01C2  1070 0C00 0030 C0C0
01C1  1D60 0C00 000C 00C0
01C0  2060 0000 0C00 00C0
01BF  1D00 0000 003C 00C0
01BE  1CF0 0003 0000 00C0
01BD  1C50 0000 0C00 00C0
01B6  1BC0 0000 0030 00C0
01A3  20C0 00C0 0030 0040
0183  1090 0000 0000 C040
0175  1830 0000 0C00 0040
0170  1750 0000 0000 00C0
0126  13E0 0000 0030 C060
0108  10AC 0000 0000 C060
00FF  13EC 0000 0000 0060
00F0  10A0 0000 0000 0060
00EB  13C0 00C0 0C30 0060
00D2  1130 00C0 0000 C060
00D1  1800 0000 0030 0040
00CF  13C0 0000 000C C060
00CB  1130 0003 0030 0060
00CA  0E30 0000 0030 004C
00C6  1130 0000 0C00 C060
00C5  1230 00C0 0C00 0040
00C4  1130 0900 0030 0060
00C3  1230 00C0 0000 0040
00C0  1130 0000 0000 0060
00BF  0E30 0000 0070 C040
00B9  1130 0000 00BC 0060
00B5  0E30 0000 0000 0040
00B0  0E30 0000 0C30 004C
00AC  0B0C 00C0 003C 00C0
00A6  0B20 0000 0000 0040
00A3  0B50 00C0 0030 006C
0090  0B5C 0000 0000 C060
0083  0B5C 0000 0C30 0060
0081  0A6C 00C0 0000 C04C
0075  0B5C 0000 0030 0060
0073  0A60 0000 0030 0040
0062  0B50 0000 0030 0060
0060  0730 0000 0000 0040
005D  0730 0000 0030 C040
005A  0810 0000 0C30 0040
0040  0B50 00C0 0000 0060
004A  1D7C 0000 0C30 C040
0049  210C 0000 0000 0040
0046  20A0 00C0 0000 0040
```

```
0C93  1400 0000 0C3C C040
0C40  0010 0000 0030 0040
0C3D  0CA0 0000 0000 004C
0C3A  0C5C 0000 0C3C C04C
0C37  0C3C 0000 0000 0040
0C34  0000 0000 0C30 0040
0C31  00F0 0000 0C0C 0040
002E  04A0 0000 0000 0040
0C2B  10A0 0000 0C30 0040
0024  13E0 00C0 0C00 0060
0021  0D20 0000 0C3C 0040
0015  10A0 00C0 0C3C 0060
000F  13C0 00C0 0030 0060
 0 ERRORS '   728 CARDS.   3969 TOKENS.      6700 RULES.      507 SECONDS.
# DUP FILE ON DISK:UYK7-LOADER
INVALID ARGUMENT: FILEID 4            0    1:1209.1     ##########################################
```

APPENDIX D. SAMPLE AN/UYK-7 SORT PROGRAM

This appendix provides a copy of a sample program which was used to demonstrate the capability of the D-Machine to function as an AN/UYK-7. The program, written in AN/UYK-7 Machine Language, will read twelve numbers per card, print the numbers, sort the input and print the sorted results. Any number of cards could be read and sorted until the "END" card is encountered. At this point the program would reinitialize memory and be ready to accept the next program. Several of the Loader's macro functions, including the L, W, D and N options, were utilized along with the appropriate formats for the five instruction types. It must be emphasized that when this program was run the ALGOL Machine had been removed and the D-Machine reconfigured through microprogramming to be an AN/UYK-7. The entire output format and program execution were produced by the Loader/Emulator combination with the IOP being used strictly as an Input/Output Channel. Examples of the Loader and Debugger output optional listings for this sample program are presented in Appendix E and F.

```
L  00002       ORIGIN SORT ROUTINE AT LOCATION 0002
D  01001       10
   203320001001
   110310001002
   440310001002
   532220000014
   523220000003
   102320001000
   512420000021
   320020001000
   201320000777
   514020000002
   101310001002
   241310001001
   240310001002
   330020001000
   514020000006
   201320001000
   530000004040    JUMP TO TITLE ENDING ROUTINE
O  04000        BEGIN TITLE PRINTING ROUTINE AT 04000
   071400005000
   071400005352
   071400005352
   070400001022
   071400005044
   071400005352
   071400005110
   071400005352
   071400005154
   070410001002
   106320001002
   446320005416
   531220004060    JUMP TO COMPLETION ROUTINE IF END CARD
   071400005352
   071400005220
   071400005352
   071400005352
   071410001002
   510000000002    JUMP TO BEGINNING OF SORT ROUTINE
O  04040   RETURN HERE FROM SORT ROUTINE AND FINISH TITLES
   071400005352
   071400005352
   071400005264
   071400005352
   071400005330
   071400005352
   071400005352
   071420001002
   071400005352
   071400005352
   510000004011
O  04060   START COMPLETION ROUTINES HERE
   071400005352
   071400001002     PRINT END
   7706000          TERMINATE PROGRAM AND RESTART EMULATOR
```

```
W  05000          AN/UYK-7  EMULATION  DEMONSTRATION  PROGRAM
W  05022
W  05044     THIS IS A TEST OF THE AN/UYK-7  EMULATION
W  05066
W  05110      USING A MACHINE LANGUAGE PROGRAM
W  05132
W  05154    FOR A DEMONSTRATION SORT ROUTINE USING
W  05176
W  05220       THE FOLLOWING INPUT NUMBERS:
W  05242
W  05264     THE RESULTS OF THIS SORT
W  05306
W  05330         ARE AS FOLLOWS:
W  05352
W  05374
W  05416END
N  04000

 123 456 789 987 654 321 023 456 875 888 555 213
 357 652 389 123 583 742 928 654 987 248 965 281
 321 654 987 123 456 789 369 258 147 963 852 741
END     TERMINATE SORT ROUTINE, READY FOR NEXT PROGRAM
```

APPENDIX E. SAMPLE LOADER OUTPUT LISTING

This appendix provides a copy of the output received from the Loader when the sample program discussed in Appendix D is run. This output is obtained by turning on the IRQ switch on the Loader's Interpreter. The output serves as a hard copy program listing for the programmer and can be utilized for debugging. The address to the left of each instruction is the octal assignment for that instruction, derived from the last "O" or "L" card, and was offset by 1024. The Loader input is terminated by an "N" card which initializes the PAR and signals the Emulator to commence execution.

```
L '00002        ORIGIN SORT ROUTINE AT LOCATION 0002
0  01001        10
2002        2033200001001
2003        1103100001002
2004        4403100001002
2005        5322200009014
2006        5232200009003
2007        1023200010000
2010        5124200009021
2011        3200200010000
2012        2013200097777
2013        5190200009002
2014        1013100001002
2015        2413100001001
2016        2403100001002
2017        3300200010000
2020        5140200000006
2021        2013200001000
2022        5300000004040    JUMP TO TITLE ENDING ROUTINE
0  04000        BEGIN TITLE PRINTING ROUTINE AT 04000
6000        0714000053000
6001        0714000053352
6002        0714000053352
6003        0704300001022
6004        0714000053044
6005        0714000053352
6006        0714000053110
6007        0714000053352
6010        0714000053154
6011        0704100001002
6012        1063200001002
6013        4463200053416
6014        5312200004060    JUMP TO COMPLETION ROUTINE IF END CARD
6015        0714000053352
6016        0714000053220
6017        0714000053352
6020        0714000053352
6021        0714100001002
6022        5100300004002    JUMP TO BEGINNING OF SORT ROUTINE
0  04040     RETURN HERE FROM SORT ROUTINE AND FINISH TITLES
6040        0714000053352
6041        0714000053352
6042        0714000053264
6043        0714000053352
6044        0714000053330
6045        0714000053352
6046        0714000053352
6047        0714200001002
6050        0714000053352
6051        0714000053352
6052        5100300004011
```

```
0  04060   START COMPLETION ROUTINES HERE
6060       0714000003352
6061       0714300001002      PRINT END
6062       7706000             TERMINATE PROGRAM AND RESTART EMULATOR
W  05000           AN/UYK-7  EMULATION  DEMONSTRATION  PROGRAM
W *05022
W  05044     T418 IS A TEST OF THE AN/UYK-7  EMULATION
W *05066
W  05110      USING A MACHINE LANGUAGE PROGRAM
W *05132
W  05154    FOR A DEMONSTRATION SORT ROUTINE USING
W *05176
W  05220       THE FOLLOWING INPUT NUMBERS:
W *05242
W  05264     THE RESULTS OF THIS SORT
W  05306
W  05330         ARE AS FOLLOWS:
W *05352
W *05374
W  05416END
```

```
R *04*00
          AN/UYK-7  EMULATION  DEMONSTRATION  PROGRAM

     THIS IS A TEST OF THE AN/UYK-7  EMULATION
      USING A MACHINE LANGUAGE PROGRAM
    FOR A DEMONSTRATION SORT ROUTINE USING
       THE FOLLOWING INPUT NUMBERS:

123 456 789 987 654 321 023 456 875 888 555 213

    THE RESULTS OF THIS SORT
        ARE AS FOLLOWS:

023 123 213 321 456 456 555 654 789 875 888 987

       THE FOLLOWING INPUT NUMBERS:

357 652 389 123 593 742 928 654 987 248 965 201

    THE RESULTS OF THIS SORT
        ARE AS FOLLOWS:

123 248 201 337 339 583 652 654 742 928 965 987

       THE FOLLOWING INPUT NUMBERS:

321 654 987 123 456 789 369 258 147 963 852 741

    THE RESULTS OF THIS SORT
        ARE AS FOLLOWS:

123 147 258 321 369 456 654 741 789 852 963 987

END     TERMINATE SORT ROUTINE, READY FOR NEXT PROGRAM
```

APPENDIX F. SAMPLE DEBUGGER OUTPUT LISTING

This appendix provides a sample of the output received from the Loader when it was used as a debugger for the sample program discussed in Appendix D. This output is obtained by turning on the IRQ switch on the Emulator's Interpreter. The switch was not left set for the entire program's execution because the output requires approximately thirty pages. The IRQ switch causes all CMR registers from address 0000 to 0035 to be printed as each instruction is executed. Each time and instruction does a Y-Operand write that address is also dumped. The addresses are printed in the leftmost column and include the following information which can be used during program debugging:

OCTAL ADDRESS	DESCRIPTION
0-7	Task A-Register contents
10	Unused (always = 0)
11-17	Task Index B-Register contents
20-27	Task Base S-Register contents
30	Repeat Instruction (if applicable)
31	Current Instruction being Repeated (if applicable)
32	Current Indirect Control Word (if applicable)
33	Y-Operand for Indirection (if applicable)
34	ICW address in memory (if applicable)
35	Program Address Register

Those addresses marked "if applicable" would normally be zero, but could contain data if either the Repeat mode or

Indirection mode had been used previously in the program. The lower 20 bits of address 0035 (PAR) point to the octal address of the next instruction. The upper 12 bits of the PAR are those ASR bits which were implemented as discussed in Section C of Chapter V. It is noteworthy that the output is an eleven bit octal representation of a 32-bit binary word, thus the leftmost octal digit represents only two bits.

By utilizing this optional listing in combination with the Loader listing, the programmer should be capable of proceeding through his program step by step. This facility proved an invaluable aid in troubleshooting the Emulator as each new instruction was written and tested.

```
0C0000C0        C30000000000        000000000000        000000000000        C0000C000C00        00000C000000        C0C0C0000000
0C0000C6        E30000000C00        000000000000        000000000000        C0000C000C00        00000C000C00        C0000C0C0C00
0C0000C14       03C0000CC00         000000000000        000000000C00        00000C000C00        C0C0C002C0C         C0000022C0C0
0C000022        03000042C00         000000062000        00000102C00         C0000122C0C         C0CCC142C00         C0000162000
0C000030        C3C0000000C0        000000300000        000000000000        C0000C000000        00000C000000        C0C0C0C06000
          AN/UYK-7  EMULATION  DEMONSTRATION  PROGRAM

0C0000C0        03000C000C00        00000C000000        C0000000C000        C0000C000000        00000C000000        C0C0C0C00000
0C0000C6        C3000000C000        00000C000C00        00000C000C00        00000C000000        00C0C0000C00        C0C0C0000C0C
0C0000C14       03000000C000        00000C000000        C0C0000C0C00        C0000000C000        00000C002000        C0C0C022000C
0C0000C22       03C000042C00        000000062C00        00000102000         C0000122000         00000142000         C0C0C162C0C
0C0000C30       03000000C000        C0000000C000        00000000C000        C0000000C000        C0000000C000        C0C0C0006C01

0C0000C0        03000C000C00        C0000000C000        C0000C000000        C0000C000000        00000C00C000        C0C0C0000C00
0C0000C6        03000000C00C        00000C000000        00000000C00C        C0000C000000        C00C0C000C0C        C0C0C0C00C00
0C0000C14       03C0C0000000        00000C000000        C0000C000000        C0000C000000        00000C002000        C0C0C022C0C
0C0000C22       03000042C00         C0000062C00         00000102000         C0000122000         00000142C00         C0C0C162C0C
0C0000C30       03000000C00         00000300000         00000000C000        C0000C000000        C0000C000000        C0C0C0006002

0C0000C0        03000C000C30        00000C000000        00000000C000        C0000C000C00        00000C000C0C        C0C0C0000C00
0C0000C6        03000000C000        00000C000000        C0000000C000        C0000C000000        00000C000C00        C0C0C0C0C00
0C0000C14       C3000000C30         00000C000000        00C000000000        C0000000C00         00C000002000        C0C0C022C0C
0C0000C22       C3C000042000        00000062000         C0000102000         00000122000         00000142C00         C0C0C162C0C
0C0000C30       03000000C00         00000300000         00000000C000        C0000C000C00        00C0C0000000        C0000C0006C3

0C0000C0        03000000C30         00000C000000        0C0000C0000         C0000C000000        00000C000C00        C0000C000C0C
0C0000C6        03000000030         00000C00C00         C0000000C00         C0000C000000        00000C000C0C        C0C0C000C00
0C0000C14       03000C000000        00000C000000        C0000C000300        C0000C000000        00000C002000        C0C0C022000C
0C0000C22       03000C042C30        00000062000         00000102000         C0000122000         C0000142000C        C0C0C162000C
0C0000C30       03000000C00         00000C000000        C0000000C000        00C0C000C00         C0C0C0000000        C0000C0006C04
     THIS IS A TEST OF THE AN/UYK-7  EMULATION

0C0000C0        03000000C00         00000C000000        000000000C00        C0000C000000        00000C000000        C0C0C0000000
0C0000C6        03000000C00         00000300000         00C000000000        C0000C000000        00000C000C00        C0C0C0C00000
0C0000C14       C3000000C00         00000000C00         C0C0C0000C00        C0000C000C00        C0C0C002C00         C0C0C022000C
0C000022        03000042C00         00000062000         00000102000         C0000122C00         00000142C00         C0C0C162000C
0C000030        03000C00C00         C0000000C00         C0000000C000        C0000C000000        00000C000000        C0C0C0006CC5

0C0000C0        03000000C000        00000C000000        C0000000000C        C0000C000000        C0000C000C00        C0000000000C
0C0000C6        03000000C00         00000C000000        C0000C000000        C0000C000C00        C0000C000C0C        C0C0C000000C
0C0000C14       03000C000000        00000C000000        C0C0000C0000        C0000C000C00        C0C0C002C00C        C0C0C022C0C
0C000022        03000C042000        C0000062000         00000102000         C0000122C00         00000142C00         C0C0C162C00
0C000030        03000000C00         00000C000000        00C0000C0000        C0000C000000        00C0C000C00         C0C0C0006006
     USING A MACHINE LANGUAGE PROGRAM

0C0000C0        03C000CCC00         00000C000000        C0000C000000        C0000C000000        00C0C000C00         C0000C000C0C
0C0000C6        03000000C30         00000C000000        00C0000C0C00        00000C000000        00C0C0C0C00         C0C0C000000
0C0000C14       03000000030         00000C000000        C0C0C0000000        C0000C002C00        00C0C002C00         C0C0C022000
0C000022        03000C042C00        00000062000         C0000102C00         C0000122C00         C0000142C00         C0C0C162000
0C000030        03000C000C00        00000C000000        C0000C000000        C0000C000C00        00000C000C0C        C0C0C0006007

0C0000C0        03000000C00         00000300000         C0000C000000        C0000C00C000        00000C000000        C0C0C0000C0C
0C0000C6        03000000C30         00000C000000        00000000C00         C0000C000C00        00000C000C00        C0C0C0C0C00
0C0000C14       C3000C00C30         00000C00C00         C0C0C0000C00        00000C000C00        C0C0C022C0C         C0C0C022C0C
0C000022        03000042C00         00000062C00         C0000102000         C0000122000         C0C0C142000         C0C0C162C00
0C000030        C3000000000         00000000000         C0C000000000        C0C0C000000         00000C000C00        C0000C0C610
     FOR A DEMONSTRATION SORT ROUTINE USING
```

```
0F0000D0        03000C00CC00    000000000000    C0C000000000    C000C0000000    0000C0000C00    CC0C0C0C0C0C
0F0000E6        C3C000000C00    000000000000    000000000C00    C000C0000000    C000C0000000    C0C0C0C00000
0F0000E14       030000000C00    000000000000    C000000000C00   000000000000    C0C0C002C0C0    C0C0C022C000
0F0000E22       030000042C00    000000062000    C0000102C000    C0000122C000    0000C142C000    C000C162C00C
0F0000E30       030000000C00    000000000000    000000000000    C0000000C000    0000C0000000    CCC0C0006C11

0F0000E0        C3000C000C00    000000000000    C000000CCC00    C000C000C000    C000C0000000    C0CC00000000
0F000006        030000000C00    000000000000    000000000C00    C00CC000CC00    C00CC000C000    CCCCC0000000
0F0000E14       030000000C00    C000000000C0    000000000C00    C000C000CCC0    0000C002C0C0    C0000022C000
0F0000E22       C3000C042C00    C00000062000    C0000102C000    C0000122C000    0F000142C000    C0C0C162C00C
0F0000E30       030000000C00    000000000000    C000000000C0    C000C000C000    0000C000C00C    C0000006C012

0F0000D0        03C0C0000000    000000000000    0000C000C00C    C000C0000C00    0000C000C00C    CC00C000CCC0
0E000006        050002010C03    000000000000    C000000000C0    C00CC000C00C    0000C000C00C    C0CCC0000000
0F0000E14       C3C000000000    000000000000    000000000000    C000C0000000    0000C002C0C0    C0000022C00C
0F0000E22       030000042C30    C0000062C000    C0000102C000    C0000122C000    0000C142C000    C0C0C162C00C
0F0000E30       03C0C0000000    000000000000    0000C000C00C    C000C0000000    0000C0000000    C0C0C0061C13

0F0000D0        03C000000000    000000000000    C000000000C0    C000C000C000    C000C000C00C    CCCCC000CC00
0E000006        050002010C03    000000000000    C000000000C0    C000C000C00C    0000C000C00C    0000C000C000
0F0000E14       030000000000    000000000000    000000000000    C000C0000000    0000C002C000    C0C0C022C0C0
0F0000E22       030000042C00    000000062C00    000001020000    C000012200C0    C000C142C000    C0C0C162C00C
0F0000E30       030000000000    000000000000    000000000000    0000C000C000    0000C000C00C    10C0006C0014

0F0000D0        03C0C000C00C    0000C0000000    000000000000    C000C0000000    0000C000C00C    C000C0C0C0C0
0E000006        050002010003    000000000000    000000000000    0000C000C00C    0000C000C00C    C000C000C0C0
0F0000E14       C3C0C000C00C    0000C0000000    C000000000C0    C000C0000000    0000C002C000    C0C0C022C0C0
0F0000E22       030000042C00    000000062000    0000C102C000    0000C122C000    0000C142C000    C0C0C162C00C
0F0000E30       030000000000    000000000000    000000000C00    C000C000C000    0000C000C00C    10C0C0C6C015

0F0000D0        03000C000C00    0000C0000000    000000000C00    C000C0000000    C0C0C000C000    C000C000C0C0
0F000006        050002010003    000000000000    000000000000    0000C000C00C    0000C000C00C    C0C0C000C0C0
0F0000E14       030000000C00    000000000000    000000000C00    C000C0000000    0000C002C000    C0C0C022C0C0
0F0000E22       03000042C030    000000062C00    000001020000    0000C122C000    C000C142C000    C0C0C162C00C
0F0000E30       C3000C0CC000    C000C0000000    000000000C00    C000C0000000    0000C000C00C    10C0C0C6C016
      THE FOLLOWING INPUT NUMBERS!
0F0000D0        03000000C00C    0000C0000000    000000000000    C000C0000000    0000C000C00C    C0C0C000C0C0
0F000006        050002010003    000000000000    000000000000    C000C0C0C0C0    C0C0C0C0C0C0    C0C0C0C0C0C0
0F0000E14       C3000000C030    0000C000C00C    000000000000    0000C0000000    0000C002C00C    C0C0C022C00C
0F0000E22       030000042C00    000000062000    000001020000    C000C122C000    C000C142C000    C0C0C162C0CC
0F0000E30       C3C0C0000C00    000000000C00    000000000000    C000C0000000    C000C000C00C    10C0C0C6C017

0F0000D0        03C000000C00    000000000000    C0C000000000    C000C0000000    C000C000000C    C0C0C0C00000
0F0000E6        050002010C03    000000000000    C0C000000C00    0000C0000000    C000C000C00C    C000C000C00C
0F0000E14       03C000000C00    C000000000C0    C000000C000     C000C0000000    0000C002C00C    C0C0C022C0C0
0F0000E22       030000042C00    000000062000    000001020000    C000C122C000    0000C142C00C    C0C0C162C00C
0F0000E30       03C0C0000C00    000000000000    C000C0000000    C000C0000000    C000C000C00C    10C0C0C6C20
 123 456 789 987 654 321 C23  456 875  888 555 213
0F0000D0        03000000CC30    000000000000    C000C0000000    C000C0000000    0000C0000000    C0C0C0000000
0F000006        050002010C03    000000000C00    C000000000C0    0000C000000C    0000C000C00C    C0C0C0000000
0F0000E14       C3000000C30     000000000C0C    C0C000000000    C000C0000000    0000C002C0C0    C0C0C022C000
0F0000E22       030000042C00    000000062000    00C001020000    C000C122C000    C000C142C000    C0C0C162C000
0F0000E30       03000C000C30    000000000000    000000000000    C000C0000000    00CC0000C00C    10C0C0C6C22
```

```
0C000006  05000201C03  000000000000  00C00000000  C0000C000000  C000CC000C0C  CCC0C000C000
0C000014  03000000C00  000000000000  000000000000  C000C000000  C000CC002C00  C000C022000C
0C000C22  0B000042C00  000000062000  C00001C2000  C000CC122000  C000C142C00  C0CC0162C00
0C000030  03000000C000  0000C0000000  000000000000  C0000000000  000CC000000  10CCC002C07

0C000000  C3000000C00  000003000000  000000000C00  0000C000000  0000C000000  C0CCC000000
0C000006  05000201C03  000000000000  00000C000000  C0000000000  C000C0C0C00  C0CCC000012
0C000014  03000000C00  000000000000  000000000000  C000C000000  000C002C00  C0CCC022000
0C000C22  0B000042C00  000000062000  C0000102C00  C0000122000  C000C142000  C0CCC162C00
0C000030  03C0C000C00  C0000000000  C0000000000  C0000000C00  0000000000  10000002C03

0C000C00  05000201C03  000000000000  C000C000C00  C000C000C00  C000C000000  C0000000C000
0C000006  05000201C03  000000000000  C000C000C00  C000C000001  0000C000000  C0C0C0C0012
0C000014  03000000000  C00C0000000  000000000000  0000C000000  C000C002C0C  C0C0C022000
0C000C22  03000042C00  000000062C00  C0C0010200C  C000C122000  C000C142C0C  C0C0C162000
0C000C30  03C0C000C30  000000000C0C  C0000000000  C0000000C00  0000C000000  10C0C002C04

00000C00  05C00201C03  000000000000  C0000C00000  C000C000000  C0000000000  C0C0C000000
00000006  05000201003  000000000000  C0000000000  C000C000001  C000C000000  C0C0000012
0C000014  03000000000  C0000000000  00C0000C000  C0000000000  0000C002C00  C0CCC02200C
0C000C22  03000042C00  000000062000  0000010200C  03000122000  C000C142C00  C000C162C30
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00000006  05000201C03  00000C000000  00C00000000  C0000000001  000000000C0  C0C0C0000011
0C000014  03C0C000C00  000000000000  00C00000000  C000C000000  C000C002000  C0C0C022C0C
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0C000C00  05001002406  000000000C00  00C0C000000  C000C000000  0000C000000  C0C0C000C00
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0C000022  03000042C00  000000062000  0000C102000  C000C122000  C000C142000  C000C162000
0C000030  03C0C000000  000000000000  0000C000000  C000C000C00  0000C000000  C0C0C002004

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0C000030  03C0C000C00  000000000000  0000000000C  C000C000000  C0C0C000C00  C000C002C05

0C000C00  05001002406  000000000C00  0000000000C  C000C000000  0000C000000  C0C0C000000
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00000014  03C0C000000  000000000000  C0000000C00  C000C000C00  C000C002C00  C0C0C022000
0C000022  03C0C042C00  000000062000  0000C102000  C000C122C00  C000C142000  C0C0C162000
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0C000C00  05001002406  0000C000C00  C000C000C00  C000C000000  C0C0C000C00  C0C0C000C00
00000006  0500F201C03  000000000000  C0000000C00  C0000000002  0000C000000  C0C0C000010
0C000014  03000000000  000000000C00  0000C000000  C000C000000  C000C002C00  C0C0C022C0C
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0C000030  03C0C000C00  000000000000  000000000000  C000C000C00  C000C000C0C  C000C0C2003

0C000C00  05001604011  000000000000  C0000000000  C000C000C00  0000C000C0C  C000C000000
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0C000014  03000000000  000000000000  0000000C00  C000C000C00  000CC002C00  C0C0C022000
0C000022  03000042C00  000000062000  0000010200  C000C122000  C000C142000  C0CCC162000
0C000030  03C0C000C00  000000000000  C0000000C0C  C000C000C00  C000C000C00  C0C0C002004
```

```
0CD00C06        05000201C03     00000C000000    C000C0000000    0000C000003     0000C000C00     C0C06000C010
00000014        03C0C0000C00    00000000000     C0000000000     C0000000000     00C00002C0C     C0C0C022C0C
00000022        07000042C00     00000062000     C0000102C00     C0000122000     C0000142000     C000C162000
0C0000C30       03000C000C00    00000000000     000C00000000    C000C000000     00000C000000    C0C00C002C05

0CD00C00        05001604011     00000000000     C0000000C00     C0000000C00     C000C0C0000     C000C000C0C
00D00C06        05000201003     00000000000     C0000000C00     0000C000003     0000C000000     C0CCC000010
0C0000C14       03000000CC00    00000C000000    00C000000000    C000C000000     C000C0002000    00CC0022C00
0C0000022       07000042C00     00000062000     0000C102000     0000C122C00     0000C142000     C0C00162000
0C0000C30       03000C000C00    00000C000000    000000000000    C000C000000     C000C000C0C     C0CCC002C0E
```

THE RESULTS OF THIS SORT

ARE AS FOLLOWS:

123 123 213 321 456 456 555 654 789 875 898 987

THE FOLLOWING INPUT NUMBERS:

357 652 389 123 593 742 928 654 987 248 965 281

THE RESULTS OF THIS SORT

ARE AS FOLLOWS:

123 248 281 357 389 593 652 654 742 928 965 987

THE FOLLOWING INPUT NUMBERS:

321 654 987 123 456 789 369 258 147 963 852 741

THE RESULTS OF THIS SORT

ARE AS FOLLOWS:

123 147 258 321 369 456 654 741 789 852 963 987

END TERMINATE SORT ROUTINE, READY FOR NEXT PROGRAM

GLOSSARY

Active Status Register (ASR): A special word in the AN/UYK-7 used to indicate the status of special conditions or modes of operation. Each bit of the word has a separate meaning to the central processor.

ADO: The Burrough's Advanced Design Organization, Paoli, Pennsylvania, which designed the Naval Postgraduate School's D-Machine.

A Registers (A1, A2, A3): Each of the three A registers is functionally identical. The A registers are used for temporary data storage within the Logic Unit of the Interpreter and serve as a primary input to the adder.

Adder: The adder in the Logic Unit of the Interpreter, is a *modified version* of a straightforward carry lookahead adder. It is also used for executing logic operations.

Alternate Microprogram Count Register (AMPCR): The AMPCR is a 12-bit register in the Memory Control Unit of the Interpreter, which contains the jump or return address for program jumps and subroutine returns within a microprogram.

AMPCR: Alternate Microprogram Count Register.

Arithmetic (A) Registers: There are two sets of eight Arithmetic Registers in the AN/UYK-7. They are used extensively in arithmetic calculations and are directly addressable by the programmer.

ASR: The Active Status Word in the AN/UYK-7.

B Register: The B register is the primary interface between the Logic Unit of the Interpreter and the Data/Program Memory or Devices through the Switch Interlock. It also serves as a secondary input to the adder.

Barrel Switch: The barrel switch is a matrix of gates in the Logic Unit of the Interpreter, used to shift a parallel data word any number of places to the left or right in a single clock time.

Base Registers 1 and 2 (BR1, BR2): The Base Registers are two 8-bit registers in the Memory Control Unit of the Interpreter, which usually contain the base address of a 256-word block of Data/Program Memory.

Base (S) Registers: There are two sets of eight Base Registers in the AN/UYK-7 used extensively in multi-programming and multi-processing. Base registers are used for operand address calculations.

BR1 and BR2: Base Registers 1 and 2 in the Interpreter.

Building Block: The term used to describe the primary functional units of the Interpreter Based System and includes: Interpreter, Data/Program Memory and Switch Interlock.

Control Memory Registers (CMR): A block of 89 registers in the AN/UYK-7 used for special fast memory operations.

Condition Register (COND): The COND is a 12-bit register in the Control Unit of the Interpreter and is used to store various condition bits for use during program execution.

Central Processing Unit (CPU): The primary arithmetic and control unit in a conventional computer system.

Condition Select: The condition select is a matrix of gates in the Control Unit of the Interpreter that computes the results of a computation or logic operation in the Logic Unit with a preselected result. The results of the comparison may be used to determine the sequence of execution of microprogram instructions.

Control Unit (CU): The CU, one of the five functional units of the Interpreter, is used for condition testing and the storage and distribution of enable signals received from the nanoinstructions.

Counter (CTR): The CTR is an 8-bit counter in the Z register section of the Memory Control Unit of the Interpreter, used for loop control and other counting functions.

CTR: Counter in the Interpreter.

Data/Program Memory: The Data/Program Memory of the Interpreter, also called S-Memory, provides storage for data and program, and functions similarly to the main memory modules of a conventional computer system.

Emulation: Describes a process through which the hardware components of one machine (Host) are made to "appear" to assume the specific characteristics of the hardware of another machine (target).

End-Around-Shift: A shift operation in either the left or right direction, in which the bit or bits which would be shifted out of the register are reinserted in the more significant end.

End-Off-Shift: A shift operation in either the left or right direction, in which the bit or bits shifted out of the register are lost. Vacated bit positions are automatically replaced by zeros.

Firmware: In the Interpreter Based System, firmware is the combination of stored logic in the micro-memory and the hardware logic of the Interpreter.

GC Bits: A set of two (GC1, GC2) global condition bits in the Interpreter. They are used as lockouts during communications to the I/O processor.

HALFFETCH: A subroutine written for the Emulator, which is executed when a halfword instruction has been decoded.

Horizontal: A type of microprogramming instuction which controls multiple gates simultaneously allowing parallel functions to execute.

Host: A term used in Emulation to define the machine on which another machine is to be emulated (imitated). In this thesis the Burrough's D-Machine.

ICW: Indirect Control Word in the AN/UYK-7.

IFE1CH: A subroutine written for the Emulator, which reads the next instruction from main memory, deciphers the Op-code and passes control to the appropriate Op-code execution subroutine.

Incrementer (INCR): The INCR is in the Memory Control Unit of the Interpreter and increments the address of the next microinstruction to be executed by the Interpreter by zero, one or two, depending on the successor instruction which is either implied or specified. A WAIT causes an increment by zero, a STEP causes an increment by one, and a RETN causes an increment by two.

Indirection: An addressing technique or mode of operation of the AN/UYK-7 in which Y-Operand address calculation points to an Indirect Control Word (ICW) which in turn points to the operand or another ICW. Indirection is determined by the i-field of an instruction.

Indirect Control Word (ICW): The ICW is a 32-bit word in the AN/UYK-7 used in Indirection which can be broken down into several fields. The fields determine the mode of indirect address calculation to be used in pointing to the next ICW or the Y-Operand.

Indexing: An addressing technique wherein the normal address calculated is incremented/decremented (indexed) by the value in the specified index register.

Index (B) Register: There are two sets of seven Index Registers in the AN/UYK-7. They provide the ability to perform Indexing during memory referencing, and may also be used as counters.

INT: An Interrupt signal issued by an Interpreter.

Interpreter: The Interpreter is the basic building block of the Interpreter-Based System. Functionally, it is characterized by the combination of microprogram instructions stored in its M memory and the combination of bits in its nanoinstruction which enable signals to implement the hardware logic.

Interpreter-Based System: A computer design concept that provides, in the form of basic building blocks, the throughput and flexibility for a variety of data processing requirements.

Interrupt: In the AN/UYK-7, the Interrupt signals the central processor to cease its normal instruction flow and respond to a request for services. In the D-Machine, Interrupt (INT) is a flag which may be set between processors signalling that a message has been placed in the Mailbox.

Least Significant Bit (LSB): For a number or value represented in binary notation, that bit position which represents the least significant portion of the number.

LIT: Literal Register in the Interpreter.

Literal Register (LIT): An 8-bit register in the Z section of the Memory Control Unit of the Interpreter, which is used for temporary storage of literals from microinstructions.

Logic Unit (LU): The LU is one of the five major functional units of the Interpreter. It performs all of the artihmetic, Boolean logic, and shifting operations of the Interpreter.

Mailbox: An address (64K) in the Interpreter's S-Memory which is used for passing messages between Interpreters and the IOP.

MAR: Memory Address Register in the Interpreter.

Memory Address Register (MAR): The MAR is an 8-bit register in the Memory Control Unit of the Interpreter, which contains the least significant 8 bits of a memory or device address.

Memory Control Unit (MCU): The MCU is one of the five major functional units of the Interpreter. It controls the sequence of execution for microinstructions; the addressing of Data/Program Memory; and the selection of devices.

Memory Information Register (MIR): The MIR is a register in the Logic Unit of the Interpreter which serves as the output interface register between the Interpreter and the Switch Interlock.

Microprogram Address Control Register (MPAD CNTL): The MPAD CNTL, a register in the Memory Control Unit of the Interpreter - controls the loading of the MPCR and the AMPCR, and determines the value of the increment.

Microprogram Count Register (MPCR): The MPCR, located in the Memory Control Unit of the Interpreter, is a 12-bit register that usually contains the address, in M-memory, of the microinstruction presently being executed by the Interpreter.

Microprogram Memory (M-Memory): The M-Memory is one of the five major functional units of the Interpreter. It stores microinstructions which characterize the Interpreter for a given application, and may be implemented as a read/write semiconductor memory.

Microprogramming: A technique for implementing the control functions of a digital computer using programmable control signals in a separate memory called a control store, which is organized on a word basis.

MIR: Memory Information Register in the Interpreter.

Monoprogramming: A general computer operating environment in which one program at a time is executed.

Most Significant Bit (MSB): For a number or value represented in binary notation, that bit position which represents the most significant portion of the number, or the sign of the number.

MPCR: The Microprogram Count Register in the Interpreter.

Multiprogramming: A general computer operating environment in which more than one program at a time is executed with each given a fixed time slice.

Multiprocessing: A general computer operating environment in which two or more central processors execute simultaneously, and share resources; such as, memory and I/O devices.

Multiprocessor: A network of computers capable of simultaneously executing two or more programs or sequences of instructions by means of multiprogramming, parallel processing or both.

Nanoinstruction: A single instruction stored in N-Memory of the Interpreter, the contents of which constitue 56 unique signals for controlling hardware logic of the Interpreter.

Nanomemory (N-Memory): The N-Memory, one of the five functional units of the Interpreter, stores 56 specific enable signals for the hardware logic within the Logic Unit, Control Unit, and Memory Control Unit.

Page: A grouping of addresses of fixed length. In the Emulator the AN/UYK-7 memory was treated as eight pages of 8K each.

PAR: Program Address Register in the AN/UYK-7.

Program Address Register (PAR): A register in the AN/UYK-7 which holds the address of the next instruction to be accessed.

Port Select Unit (PSU): The PSU provides control and the electrical interface between a single Interpreter and its Devices and Data/Program Memory.

Shift Amount Register (SAR): The SAR is a 6-bit register in the Control Unit of the Interpreter and is used to store the number of positions a word or literal is to be shifted by the barrel switch.

Switch Interlock (SWI): The SWI provides the interconnection between Interpreters, Data/Program Memory, and Devices of an Interpreter Based System. Its function is to permit any one of a multiplicity of Interpreters to access all modules of an array of Data/Program Memory and/or all Devices.

Target: A term used in Emulation to define a machine to be emulated (imitated). In this thesis, the AN/UYK-7.

TRANSLANG: A computer programming language designed to convert pseudo-English language statements defining the action of the Interpreter for each machine cycle into binary patterns for the M-Memories.

Vertical: A microprogramming instruction which controls those gates needed for a single function execution.

Z Register Section: A collection of registers and selection gates in the Memory Control Unit of the Interpreter, which includes the CTR, LIT, and Input Selection gates used to control the execution sequence of microinstructions.

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